LECTURES

In a Workshop.

BY

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WITH AN APPENDIX CONTAINING

The Famous Papers by Whitworth "On Plane Metallic Surfaces, or True Planes;" "On an Uniform System of Screw Threads;" "Address to the Institution of Mechanical Engineers, Glasgow" "On Standard Decimal Measures of Length"

NEW YORK:
THE INDUSTRIAL PUBLICATION COMPANY.
1882.

In Memoriam.

THOMAS PHILLIPS PEMBERTON,

OF LIVERPOOL, ENGLAND.

ESTEEMED BY ALL WHO KNEW HIM IN PUBLIC AND PRIVATE LIFE, AS ONE OF NATURE'S NOBLEMEN.

TO WHOSE LOVE, ENCOURAGEMENT, LIBERALITY, AND INFLUENCE, THE AUTHOR OWES HIS EDUCATION AND EARLY TRAINING IN OFFICE AND WORKSHOP.

PREFACE.

This small but comprehensive volume forms an appropriate sequel to "The Student's Illustrated Guide to Practical Draughting," which is now in the hands of a great many students throughout the United States; and carries forward another step our wish for popularizing and widely diffusing good and useful, and practical information, among the thousands of industrial workers in handicraft.

The "Lectures" have been written with the aim of stimulating young men and workmen to self-culture, and of showing to them in plain language the unprecedented and splendid opportunities and means for education and improvement. Still more to show their capabilities in adding immensely to the rapid progress in industrial art and practical science. The valuable papers by Sir Joseph Whitworth, of Manchester, England, the eminent mechanician and inventor—a self-made, self-cultured man—will be read with interest and profit.

The Author trusts that this work will be found acceptable and instructive, and be the means of inciting many to more exertion and higher aims in their employment and acquisition of knowledge.

LECTURES IN A WORKSHOP.

LECTURE I.

There is no necessary connection between manual labor and degradation; no essential disjunction of the work of the hands from that of the head; neither any law of nature which should make impossible, or even difficult, an alliance of good manners, high morals and elegant accomplishments, with the active duties of a mechanic. On the other hand, these things are of immense value to a workman. He cannot bring superfluous talent to his work, however simple habit may make it appear; he cannot have too much of that patience and self-denial which are found most highly cultivated in polished circles. There is no one good quality of the gentleman which can sit ill on the mechanic, however poor he may be. Labor is neither a disgrace nor a curse. Some persons regard its muscular demands as the result of sin and curse, but in the Bible, which all can read for themselves, it is said of the first man that his Maker placed him in the Garden of Eden to dress it and keep it. It would, therefore, seem to have the sanction of Scripture, when it is asserted that labor is an ordinance of the Creator for our highest and best welfare. His mechanical skill may be recognized in every prairie

flower and in every snow flake, and His exertions seen when the forces of nature are urged through the channels of vegetable life, and the bare forests and brown grass shoot forth afresh their foliage and don again their mantle of living hues; when the ice-bound streams, impelled by some mysterious agency which we call gravitation, burst their icy barriers, and obeying a common tendency, flow into a common ocean. But perhaps some will be ready to say that all do not labor; and that, while one man tugs at the printing press, and another spends his strength in striking the anvil or filing at the vise, there are others who are exempt from toil, and have little to do but to speak a few words, or to draw up a legal document, or to prescribe a remedy for disease. Now, among workingmen, and especially with mechanic apprentices, the impression too often prevails that a professional man enjoys an immunity from labor; their ideas of professional toil are all limited to the preparation for a diploma, or admission to the bar; and these once obtained, and the office taken and the sign hung out, they think there is little for the physician and the lawyer to do but to sit still and allow the money of the laboring men to flow into their pockets. Now, what is it that constitutes labor? All toil is not alike; there are some kinds of mechanical employment which demand less muscular effort than others. The watchmaker uses a much lighter hammer than the blacksmith, and the engraver works with a finer chisel than the stonemason; and yet all these may lay claim to be called mechanics, and to earn their bread by honest toil. Where, then, shall the unity of labor be found? Certainly it is not in the amount of muscular demand. Shall it be defined as production? Is it that mechanical or agricultural skill which produces the comforts of life?

The printer produces books and newspapers, and the

author produces the thoughts that make the printer's work something more than lifeless paper and ink. The copyist, too, produces manuscript which may prevent fraud and injustice. The truth is, every man who is employed, whether with the head or the hand, is a laborer and a producer. All are laborers; and if some wear working jackets while others don broadcloth, it is because it is fitting that every man should array himself in the garment best adapted to his toil. Muscular exertion is not the only labor, for there is many a studious man who would gladly exchange his aching head, and excited nervous system and sleepless nights for the clear brain and healthy tone, and sweet repose, that of themselves more than compensate for the severest muscular exertion. Indeed, the balance of ease is in many respects in favor of the men who follow the plow, or push the plane, or carry the hod, from morning till night. Headwork knows no ten-hour regulation. It cannot be set aside when the sun goes down, or suspended on account of the weather; but its demands are ceaseless, and no compensation of wealth can restore the balance and bring the headworker to an equality of ease with the manual workman. A true man feels that life is something more than a scramble for wealth, or an opportunity for vice or a thing of sloth, and, whether his pulses throb beneath homespun or are covered with purple and fine linen, he will be a worker. Toil, toil—either of the brain or the hand—is the only true manhood, the only true nobility.

If there is a dignity in labor, if the means of education are accessible to all, if intelligence is certainly recognized, what is there to prevent the mechanic from elevating himself and striving for an exalted position? And yet, out of the thousands of talented designers and ingenious mechanicians, there are very few who arrive at any degree of eminence. It is a manifest truth, that large numbers of those engaged in me-

chanical pursuits seldom trouble their heads about mental improvement. After work hours their time is frittered away in trifling; too often, we know, in vicious amusements, which absorb their attention on the following day, to the exclusion of the thought that should be given to their employment. Now, the remedy against such a worthless existence, is to go to work and use every opportunity to improve the mind and learn as much as possible about everything connected with the trade or employment that serves for daily occupation. It can scarcely be expected, after eight or ten hours' unremitting labor, that a workman should tie himself down night after night to study. He says he must have relaxation and amusement, and will produce arguments apparently plausible in order to get rid of the responsibility of self culture and mental improvement. But the man who would educate himself must have the disposition to learn. He may be chained to a shoe-bench, or fastened to a printing press, or stand at a lathe or vise all day, in order to earn his living; and yet, in his close observation of men and manners, in his education of thought, in his careful husbanding of spare moments, in judicious reading, in availing himself of all attainable means for educating himself, benefiting his fellow creatures, and becoming a useful and intelligent member of society, he will feel his self-improvement, the world growing larger, and his own soul growing with it; he will see a significance in his being, and in the world about him, of which the manufactured scholar never dreamed. To every reflecting person it must be evident, that an educated man, skilled in his trade, with a knowledge of the laws on which it is founded, is much more valuable to his employer and himself than the mere workman whose actions are akin to those of a machine, whose mind is a waste, and who seldom thinks. There are many narratives of the success of earnest seekers after education and scientific

pursuits amidst the discouragements of public opposition and poverty. Franklin rose from the position of a printer's boy to that of a prince among philosophers; John Fitch, who built in 1811 the first steamboat for the navigation of the western waters, cultivated a potato patch in order to purchase a copy of Salmon's geography; Sir Richard Arkwright, "the subterranean barber," was the inventor of the cotton machine; Sam Crompton played the violin at an English theatre for eighteen pence each night, to enable him to procure tools to make his spinning mule, and the government subsequently assigned to him £5,000 as a national reward; Chantrey, the great portrait sculptor, carried out milk in Sheffield; Murray, the great linguist, learned to write by scribbling his letters on an old wool-card with the end of a burnt heather stem; William Cobbett made himself master of English grammar when he was a private soldier; Lord Campbell, Chief Justice of England, was a parliamentary reporter; Charles Dickens was once a lawyer's clerk, and such a position in England is neither a lucrative nor an enviable one; Faraday, one of the brightest luminaries of science, was a bookbinder's assistant. Therefore there is no degree of distinction which is not open to the mechanic; enlightened workers will be appreciated as well as mere thinkers, and laborers can reap the fruits of their industry as well as mere speculators in labor.

LECTURE II.

Reference has been made to Richard Arkwright as one of those who fought their way through seemingly unsurmountable difficulties. Carlyle, in speaking of this remarkable man, says: "Richard Arkwright was not a beautiful man; no romance hero with haughty eyes, Apollo lip, and gesture like the herald Mercury; a plain, almost gross, bag-cheeked, pot-bellied Lancashire man, with an air of painful reflection, yet also of copious, free digestion; a man stationed by the community to shave certain dusty beards at a half-penny each. His townsfolk rose in a mob round him for threatening to shorten labor—to shorten wages—so that he had to fly with broken wash-pots, scattered household, and seek refuge elsewhere. Nay, his wife, too, rebelled; burnt the wooden model of his spinning-wheel, resolute that he should stick to razors rather; for which, however, he decisively—as thou wilt rejoice to understand—packed her out of doors. Oh, reader! what a historical phenomenon is that bag-cheeked, pot-bellied, much-enduring, much-inventing barber."

It is remarkable that nearly all the great inventions that have contributed so vastly to the prosperity of nations and the advancement of the world's civilization, may be traced to the efforts of individuals. Referring to history and historical records, either sacred or profane, it will be found that individual energy and individual influence have been at the birth of all great undertakings, and the prime movers of great and important events. Moses, born in obscurity, became the leader of the Jewish nation. Nehemiah had surveyed mournfully the desolations of Jerusalem, and helped to rebuild

its walls, holding a weapon in one hand whilst he labored with the other upon the works. Napoleon Bonaparte, the scourge of nations, grasped the world in his unbounded ambition, and, like Alexander, would have conquered the world by the marshalling of armies and the power of murderous weapons. Cæsar is said to have slain a million of men in his wars, and captured a million more:

"What millions died that Cæsar might be great!"

Sir Isaac Newton, in his great and philosophical mind, grasped at the universe, and with the rod of research stirred the vast ocean of truth, revealing the sublime laws which move and regulate the myriads of unnumbered worlds. Isabella, Queen of Spain, pledged her Jewelry for Columbus, by which he was aided in the discovery of half the globe. Luther and Raikes moved the religious world. Franklin sported with lightning and gave an impulse to printing. Fulton gave us our first steamboat, and Morse discovered the powers of electricity. George Stephenson, who rose from a colliery boy to unprecedented eminence as an engineer, at a meeting of engineers in Birmingham said: "Without being egotistical, I may say that I have mixed with a greater variety of society than perhaps any man living. I have dined in mines among miners, and I have dined with kings and queens, and with all grades of the nobility. I have seen enough to inspire me with the hope that my exertions have not been without their beneficial results, that my labors have not been in vain." And yet this great projector of the Liverpool and Manchester railroad could neither read nor write until he was a full-grown man, for he practiced "pot-hooks" when he was eighteen years of age. After his daily labor he betook himself to mending his neighbors' clocks and watches, in order to raise the means for educating his son Robert, who achieved

another triumph as the designer and constructor of the celebrated Victoria tubular bridge over the St. Lawrence, near Montreal. The important truth which comes to the surface from all these past events and histories, which could be enumerated *ad infinitum*, is, that the influence of individuals has been, and always will be, very great. As the century aloe blooms but once in a hundred years among the daily flowers, so above the lifeless masses of society loom up, now and then, individuals whose deeds are registered on time's eternal record; whose names have perfumed the world and been her boast, or "smelt to heaven with rank offence;" who have moved or retarded the wheels of improvement for centuries. Certain it is that—

> **"The heights by great men reached and kept,**
> **Were not attained by sudden flight;**
> **But they, while their companions slept,**
> **Were toiling upward in the night."**

In order to feel the full force of a precept or principle, we must see it exemplified in a life—see its practical workings upon individual character. We have alluded to the lives of men who have displayed indomitable energy, and carved out their own fortunes from circumstances which appeared directly opposed to their ever rising to any degree of eminence. We all give our cordial assent to a high standard of excellence, and it has been demonstrated that it is in the power of all to elevate themselves above being mere "hewers of wood and drawers of water." If a high degree of eminence has been reached in one case, it may be in another; and we know of nothing more encouraging and stimulating than to study the lives of men who have done much to advance science, and given to mankind a vast amount of useful knowledge.

If there is any doubt about what study or studies should be followed with a view to self-culture, we can remove it by a simple rule given in three words; namely, *Study your business*. By this the daily bread is to be earned; and it is highly probable that the knowledge of the trade engaged in, exceeds the information on all subjects outside of it. Many men, however, are continually attempting too much, and fret and worry because they cannot swallow whole volumes of literature and science in a few months; they are apt to slight their daily occupation as an unavoidable means of maintenance, and concentrate their efforts upon something quite foreign to their trade. Such men have mistaken their calling, and are wasting their time so far as self-improvement goes. Eight or ten hours are spent in what must become to them the merest drudgery; and as they take no interest in their work, the task of engaging in it from day to day becomes doubly irksome. Now, start fairly and honestly. Think the matter well over before adopting any line of business, and weigh well your abilities aud resources. Put down in one column all the reasons, advantages and means for a certain line of business, and in another all the reasons why such a daily occupation should not be engaged in; sum them up, and act according to the result. Is mechanism the choice, and a carpenter's, pattern-maker's, or machinist's trade the very one in which your best talent will have a chance for full development? In short, is there a strong interest in, a thorough liking for, the business? If so, it is the proper one to follow, and with steady, persevering, energetic application, success is certain to come in due season. Be, therefore, careful and honest in the selection of a business to which a whole life is to be devoted. Be sure you are right, and then go ahead, is advice which becomes appropriate in the start of a business life. Every day we see and meet men who have mistaken their calling—

clergymen who ought to have been farmers; lawyers who ought to have been ministers; tradesmen who would have adorned the professions, and professional experts who would have been excellent storekeepers and "drummers;" engineers, nominally, who would have made good watchmen; and machinists who would fill any other position well except the superintendency of a machine shop. Hence there is apathy in congregations; agriculture is deprived of intelligent laborers; corruption exists in the courts; and, in trades—blunders, failures and accidents follow each other in quick succession. Hence, again, there is a comparatively wasted life, little or nothing having been accomplished; whereas, in the appropriate sphere of labor, ease, security, success, honor and happiness would have been attained.

LECTURE III.

Adam Clarke says, "The old proverb about having too many irons in the fire is an abominable old lie. Have all in, shovel, tongs, and poker." We would, however, present such advice with caution, lest it should be misunderstood and misapplied. As already said, the proper study for every man—the one which should claim most of his attention, and demands the fullest employment of his physical and mental energies—is the business by which he is to gain a livelihood. Upon this we enforce concentration. But there are always subjects and matters to learn and to study about, which relate more or less to the main business of every man's life. For instance, we will assume the occupation shall be a mechanical one, such as the construction of machinery, carpentry, engineering, or pattern making. Now, is there nothing attached to the business of a machinist or a worker of iron but planing, turning, scraping and filing of surfaces? To file straight, to turn "true," to "make a neat finish," are all indispensable to make a good workman. These are irons that have to be in the fire. But there are others that can be kept heated without injuring, but rather improving, the condition of the others. Expertness in mechanical drawing, a knowledge of geometry, mensuration, decimal arithmetic, and proportion, and of the properties, strength and weight of metals and other materials—*those are the shovel, tongs and poker that are instrumental in keeping a machinist's business in full blast.* How many machinists of to-day can say that they are *experts* in their calling, with a *thorough knowledge* of the first principles of mechanical science? And yet men will say that they re-

ceived a good school education, learned arithmetic, writing, *studied* such and such sciences and subjects; but now, when they have entered upon a business which demands the exercise and putting forth of all they *did study*, they cannot tell how to find the circumference or area of a circle, how to calculate the mechanical powers, how to draw a bevel-wheel, or calculate a train of gearing. They have forgotten how to work by decimal fractions, and have not practiced writing or drawing. Even foremen and overseers, who are generally supposed to know more than those they oversee, are too often ignorant of the most important facts and aids in their business. These remarks apply equally well to engineers. We all know that there are a great number of ignorant engineers (falsely so called), both white and colored, in this country. The *Westfield* boiler explosion, the constant blowups on the Mississippi and other rivers, the "smash-ups" and "breakdowns" of machinery and property on land and sea, the collisions, concussions, and silly, fruitless dis-cussions, all tell of unfaithful, unintelligent engineers; while the funeral bell of thousands of human victims tolls the solemn dirge of the sacrifice of life to financial meanness, professional ignorance, and unintelligent carelessness. True it is, then, that in this, our day, we know not the things which belong to our peace; but they are *not* hid from our eyes, for we cast our dead into the sea, and fill our hospitals with the tortured bodies of the wounded.

There is no trade or business which does not require more or less energy and judicious management. Skill is needed in financiering; skill is necessary in superintendence; skill is required in manipulation of materials; and, although this skill may be acquired easily by some, it is generally only attainable by constant application, concentration and perseverance. There are mechanics to-day in England who have

served an apprenticeship of five or six years, who have been as regular as clock-work in attending to their daily employment, and who are valuable to their employers as steady, skilled workmen. But what has made them so? They have learned only one branch of the business, and by constant practice have gradually improved in the rapidity and execution of their particular work. There are hundreds of such men who, year in and year out, have never changed their manual work for anything higher or more lucrative; nay, they have not even changed their "job," but, like some of the machines they attend, will break down only when sheer old age and wear and tear compel them.

In England, proficiency in manual dexterity seems to be the highest aim of the mechanic. To be a "first-rate workman" is to have the respect of their fellow workmen and the highest approbation of the superintendent. Beyond this—the fact of accomplishing more work in a given time and doing it in a better manner than usual—the British workman has but little ambition. He is generally illiterate; and, though he can plumb, square, lay out work, exhibit ingenuity and invent all kinds of contrivances, and is equal to almost any emergency, he is frequently only able to read and write imperfectly. Hence we find mechanics and workmen coming to this country from British soil who are expert, and that remarkably so, in some particular branch of the business, and that very expertness is their hobby. Here in this country the spirit among those learning a business is different. Frequently the aim seems to be to learn as much of everything in as short a time as possible, with the least trouble and labor. Who does not know of apprentices working a year at some business, and then leaving to go somewhere in order to get a journeyman's wages? Who does not know that in every factory and workshop in this country great differences exist

in the capabilities of men engaged in different occupations? Who does not know that the most valuable man is he who understands his business thoroughly? And who does not know that the man who has worked hardest and longest, studied his business, made observations in it, read upon it, thought upon it, used brains as well as hands in it, is the man who holds a higher position and obtains a better remuneration for his services than his fellow-workman?

But mark the difference between English and American workmen. The former are content to serve an apprenticeship, to learn one particular branch which they mean to follow as their business, it may be for life; the latter expects to learn three or four branches, or the whole business in three or four years. At the expiration of such a term it is frequently found that he has acquired a smattering of several things, but made himself master of none. He has rushed forward, *looking only at the dollar*, when he should have been intently studying his business; he has been thinking how much work he could do, instead of how well he could finish it; he has been thinking, talking and agitating on more pay and shorter hours, rather than fair pay for a fair day's work; he has rambled from shop to shop, doing first one thing and then another (for he has served his apprenticeship, and of course must be considered to be master of his business), and all this for a little more pay, which pay seldom satisfies him for any length of time. There is not much surprise expressed on being informed of his "changing his business."

There is no royal road to learning; skill and proficiency are not obtainable by dollars and cents. Therefore, after a business has been decided upon with the determination to make it a business for life, with a resolution that will combat with all the difficulties, misfortunes and vicissitudes which attend more or less every undertaking, the great and grand

object to be held constantly in view is to use all the available means for acquiring a practical and thorough knowledge of that business. In the "Memoirs of Robert Chambers" may be found the following passage:

"After an interval of fifty years I recollect the delight I experienced in working off my first impression; the pleasure since of seeing hundreds of thousands of sheets pouring from machines in which I claim an interest being nothing to it! If the young and thoughtless could only be made to know this—the happiness, the dignity of honest labor conducted in a spirit of self-reliance; the insignificance and probably temporary character of untoward circumstances while there is youth, along with a willing heart; the proud satisfaction of acquiring by persevering industry instead of by compassionate donation—how differently would they act!"

LECTURE IV.

Workmen in all branches of industry have always had their periodical agitations on two subjects, viz., the hours of labor and the compensation for their services. Fair pay for a fair day's work is a reasonable rule enough for both employer and employé; but the very frequent and very natural questions, what is a fair remuneration for a day's labor? and what number of hours should be reckoned as the time for a day's labor? are continually being discussed, and that very earnestly, on the part both of employers and the employed. We have always regarded the subject as an important and an intricate one, demanding much thought, sound reasoning, and good judgment. The process of examining the facts and arguments which the capitalist can command, and the privileges and rights which the employed can claim with propriety, is one requiring the most careful consideration; involving, as it does, the principles of rectitude in the dealings of men with each other. On the one hand, there may be a tendency to arbitrariness, monopoly, selfishness, and the accumulation of wealth at the expense of those whose circumstances render them incapable of checking unprincipled dealings; and, on the other, there may be demands made, the compliance with which would be injurious to trade, commerce, and national prosperity. The strikes which are constantly being made by workmen are hurtful both to themselves and their employers. The former lose both their time and money, and not unfrequently the situations they have held for a considerable time, while the latter are unable to fill their contracts, and consequently suffer annoyance and pecuniary loss. This contest

between capital and labor is one which can never be settled until men learn to act on and be governed by the golden rule, to do unto others as they would be done by. Strikes ought never to be made use of as a means for obtaining an end. They lower the tone of good feeling, which should always exist between employers and those employed by them. The employer often yields, and puts an end to the strike, in order to escape loss, but with a vindictive spirit resolves to discharge his help or lower wages when opportunity serves his purpose; then, when that occurs, he will tauntingly inform them that his turn has come, and that, as they had formerly no consideration for his interests, he will not now consult theirs. In other words, that they took advantage of him at a time when they knew the pressing demands of his business contracts and compelled him unwillingly to accede to their demands, but that time having passed, he has now made arrangements that will render him independent of them, should they indulge in a repetition of such conduct. We have heard employers talk this way, and what is more, they acted precisely as stated. But this question arises, Are the working people to submit to just such terms as masters dictate? Are they to regulate both the amount of wages and the hours of work? We answer that, other things equal, they should have just as much to say in the matter as the employed. They know best the state of the markets, the price and quality of goods, what will find a ready sale, and on what they can obtain fair prices. If the producer can place articles in the market in quantity and at a reasonable price, do not working people get the benefit of those cheap commodities as well as any other class of citizens? It seems as if a workman ought readily to understand that, if high wages are paid and materials costly, the price of goods must also be high, and higher in proportion to the amount of the workman's wages.

Suaviter in modo, fortiter in re, the translation of which is "gentle in manners, but resolute in deed," is a motto which might with advantage be adopted by both employers and employés. The Latin quotation given here served as a caption to a description of the management of the Lea Mills, Matlock, England, furnished by John Smedley, Esq., the proprietor. The communication, which we extract from the *Scientific Press*, contains so much practical information suitable for our "Lectures in a Workshop," that we give it in full:

"We have never had a strike or any disagreement with our hands in my time, nor in my father's or grandfather's time. We have been engaged in spinning and manufacturing long before the commencement of this century. My ancestor's idea was, that those who rode inside the coach should make those as comfortable as possible, who are compelled, from the mere accident of birth, to ride outside. Acting on this principle as much as possible, our plans with respect to the employed are as follows: We commence work at the mills at 6 A.M., go on till breakfast time at eight. The hands have opportunity in the mill, previous to the bell ringing out, to wash; water, soap and towels being provided. They assemble in the dinner-house, and find hot coffee or tea, sweetened or milked, at a halfpenny per pint, or Scotch oatmeal porridge, either with Macfie's best golden syrup, or with half a pint of milk, at fourpence-halfpenny per week. All is optional. We keep a man-cook and assistants, and some boys and girls to receive any food the hands bring with them to cook. The boys and girls wait upon the hands, and in a quarter of an hour breakfast is generally finished, the remaining quarter of an hour, in fine weather, the hands stroll out, or if wet, read, knit or sew. At half-past eight a manager takes his stand at a desk in the same room, and gives out a hymn; then reads the Bible, or other works of general interest; then a short

prayer, and the choir sing, while the hands disperse to their work at nine, refreshed and cheered, and quite alert for their occupations.

"From half-past twelve to half-past one, dinner; the cooks cook anything the hands bring. The hands wash again, in our time, before coming out of the mill, and find their dinners ready, consisting of various kinds of food—bacon, meat, dough for dumplings or pasties, potatoes boiled or fried, and various other things brought by them, and tea or coffee, as at breakfast. Work again from half-past one till six, except on Saturdays, when at half-past twelve the mill is closed. Men allowed time for tea or coffee at half-past four. Christmas Day and Good Friday all wages paid in full. Loss of time for sickness not less than half wages paid, according to family; and, when in a club, the allowance generally brings it up to full wages. Women and girls, if in a club, the allowance makes it nearly equal to full wages; otherwise, one-third to one-half wages, according to circumstances. We have hydropathic hospitals, where any hands requiring treatment have board and lodging free, and half wages. If ill at home, they are fetched, if they wish, to the hospitals. If any calamity occurs, such as death in the family, or if they are detained at home from sickness in the family, we assist them; they know always where to apply for help and sympathy. Many years ago, I had to follow the changes constantly going on in manufacturing, and go into a class of goods more in general demand, in which, of course, we find keen competition; but that did not induce me to try to alter the policy towards the workpeople, and I have still found it profitable to our plans in trying to make them as efficient as possible for the work they have to do. I believe the present disagreements between employers and employed are the long neglect of consideration for the workers, and the want of sympathy and personal

knowledge and intercourse with them; and now, like a neglected family, it is bringing its natural and inevitable results, and, till this is altered, masters may meet and pass resolutions just as effective as if they passed one that there should be fine weather for the next three months.

"Not having any family or relatives to succeed me, I have kept the business down, and have only 1,000 or 1,100 hands connected with it. I could find employment for 4,000. About half the hands are on the premises; the others work in the neighborhood, at their homes, or in shops, and bring their work in on Saturdays and Mondays, when they can have hot tea and coffee, and bread and cheese, free. This saves them from calling at public houses for refreshments, at the consequent risk of spending their week's earnings, and incapacitating them for their work for a week or more, which would disappoint our customers, and we should lose the profit on the work. By this policy we have held our well-known position in our trade in spinning and manufacturing merino hosiery. We never have to ask for orders nor money; never make bad debts, nor draw nor accept bills; and, as to profit, we get what should satisfy any reasonable expectations. We pay full wages; the hands are smart and effective; no man ever loses a day from drunkenness; and rarely can a hand be tempted to leave us. We keep a supply of dry stockings for those women to put on who come from a distance, and get their feet wet; and every overlooker has a stock of macintosh petticoats to lend the women going a distance on a wet night. When I go amongst them, all recognize me, and it is always a pleasure to go through the mill. I wish I could make their lot easier; for, with all we can do, factory life is a hard one. If the hands in any branch of business have representations to make about wages or anything respecting our rules and regulations, they come freely to us, knowing

that we are always ready to listen to and grant any reasonable request. It is a sad state of things when masters have to combine against the hands, and the hands against the employers; it has just the same effect as parents combining against their children, and the children against their parents. If the children are not what they ought to be, it is very certain to be the parents' fault in not gaining their affections and confidence. '*Veritas est magna, et prevalebit.*' Truth is great and will prevail; and nothing but justice and truth can stand long."

Yes, Mr. Smedley, your views coincide with what we have already stated in our "Lectures," for you say, "with all we can do, factory life is a hard one." A proprietor with such system, forethought, and consideration for the comfort of his employés, is well worthy of imitation.

LECTURE V.

Numerous associations have been organized from time to to time by mechanics and operatives; and this proves that those who are termed working men are capable of combining together for the attainment of some special object. The ends sought may be legitimate or not; the advantages held up to view may be real or not; sanitary reform and social progress may or may not be advanced by the success of certain measures sought and obtained by any body of men who desire a change in affairs that directly concern themselves; but this fact is established, that mechanics and tradesmen can organize, have an interchange of ideas, discuss and argue their points *pro* or *con*, draw up resolutions, frame constitutions and by-laws, and enforce measures, all tending to the establishment and strength of their association, and the promulgation of their ideas and principles.

Keeping this fact in mind, we turn to examine the institutions and associations of the present day that have for their especial object the social and mental improvement of workmen. At the outset we state, that taking into consideration the vast extent and resources of this country, the enormous population, the great wealth, the rapid progress, the enterprising spirit of the people, the democratic form of government, the means of education, the general intelligence of the people, the constant influx of foreigners, the facilities for appropriating all that is grand, great, and useful in art and science—with such a country, with such a people, with such facilities and advantages, we should naturally suppose that institutions for industrial education would be among the most

prominent in the land. But are they? Setting aside the public institutions of a sanitary and reformatory character, and public schools, which are instituted in a greater or less number throughout the various States, we find a host of political, religious, social, scientific, literary, musical, medical, mercantile, and charitable societies, firmly established, well organized, well supported and enriched with endowments.

But where are our grand industrial schools?—institutions where, at trifling cost, the mechanic can educate himself in the theoretical as well as the practical part of his business; where the engineer can learn the nature of steam and metals, as well as the principles of good workmanship; where the dyer can learn the properties of chemicals; where, in short, mechanics, drawing, mathematics, hydraulics, chemistry, navigation, and other sciences, are taught in a plain, illustrative, comprehensive manner by practical experts competent to interest and teach men of ordinary intelligence. We can almost count the number on our fingers; and some of these are Mechanics' Institutes only in name, and do not meet the demands and requirements of the industrial classes. State prisons and State reformatory institutions for the unfortunate and vicious, should be balanced by institutions for industrial education and the mental improvement of the industrial classes. The workingmen are an immense power in this and all other civilized countries; they are the bone and sinew of their greatness and prosperity; but as yet their influence and power are only partially developed. Great, grand, and glorious discoveries are yet to be made by educated workmen; and it is possible that institutions can be founded and supported by them, and them alone.

Among the institutions organized for the purpose of affording industrial education, none seem to stand more prominently than the Worcester Technical Institute, located in

Worcester, Mass.; the Stevens Institute at Hoboken, N. J.; the Massachusetts Institute of Technology, in Boston; the Cooper Institute in New York City. There are a limited number of colleges where studies in the sciences can be prosecuted with excellent facilities for illustration, experiment, and practical demonstration. But to our mind and in our judgment the Worcester Technical Institute is one that could be copied with advantage in every manufacturing city, and we will give a sketch of it. The main buildings are two in number, one of stone and another of brick, and are located on an eminence which commands a fine view of the city of Worcester and its environs. The buildings are imposing in appearance, being strongly built, and surrounded by grounds laid out in a tasteful manner. One of these buildings is devoted entirely to educational purposes, and contains the offices of the principal and officers, class-rooms, lecture halls, laboratories, etc.; the other is a machine and wood-working shop fitted up with every convenience and necessary appliance for the construction of light machinery, models, patterns, and fancy articles. In these works a few very expert workmen are kept, part of whose business it is to instruct students in the use of tools and the principles of workmanship. Here the young men put themselves in the position of apprentices, and receive the fullest advantages of unlimited means in the shape of tools, and instruction of the soundest and most practical description. It is this practical instruction, accompanied by all the means and appliances for conveying it to the intelligence of students that makes this institution so valuable and grandly successful. In its scope and purpose it is essentially like the technical schools of Europe; but gives special prominence to the element of practice. Here boys and young men get a good education, based on the mathematics and the physical sciences, and, by study and proper attention get

to know enough of some art or trade to enable them to earn a living when they leave school. The course of instruction is so planned that students can acquire thorough elementary knowledge of at least one of the following branches: 1. Mechanical engineering; 2. Civil engineering; 3. Architecture; 4. Drawing and Design; 5. Chemistry; 6. English, French, and German. Certain studies are common to all these departments; for it is the aim of the school to give as complete a general education as possible, and to point out the true relation of theory and practice. The course of study covers three years—senior, middle, and junior. The students who enter the machine shop are advanced as fast as possible. They are not kept at cleaning castings, and doing the drudgery of the shop, any longer than is necessary to teach them how to do it. They are thus relieved of one hindrance generally experienced by apprentices, who are required to do all the rough work of the shop, on the ground that in this way the owners can get some compensation for the subsequent labor of teaching them. The students, therefore, have three advantages, viz., the discipline and culture of free-hand drawing, careful distribution of their time, and relief from all unnecessary drudgery. To these should be added the consideration, which far outweighs them all, that the boys come to their work with the perceptive faculties, the reason, the judgment, and the taste, all under constant and careful training in school. Theory and practice accompany and supplement each other, and both may pre-suppose the actual possession of the elements of all knowledge. The school was founded by John Boynton, Esq., of Templeton, in 1865, and in his letter of gift, dated May 1, 1865, he says, "I have determined to set apart and give the sum of $100,000 for the endowment and perpetual support of a free school or insti-

tute, to be established in the County of Worcester, for the benefit of the youth of that county."

We advocate the founding of many such institutions throughout the country. They are wanted; they will always be patronized; they are grand in their results of usefulness; they advance learning and science in the most practical and attractive form; they are the means for developing inventive talent; and lastly, they afford a young man all the facilities for improving himself in knowledge which he can turn to good account in after life, whether the occupation of that life be professional or industrial. We claim that such institutions can be founded, organized and maintained by the industrial classes themselves in all large cities, and wealthy manufacturers seldom, if ever, evince any indisposition to contribute liberally towards the promotion and success of such an enterprise.

LECTURE VI.

Our subject is Self-Educaton. Young men engaged in mechanical pursuits are generally desirous of cultivating their minds, and of acquiring scientific knowledge, but their opportunities are extremely limited. Public night schools are not suited to an ambitious young man; his wants are different from what they supply, and he aims at higher attainments than they can bestow. Classes conducted by private teachers do not meet his views; for either the teachers are incompetent, or the charges are too high; and even if both teachers and charges were unexceptionable, the unequal intelligence and unequal attainments of the pupils, together with their want of punctuality in attendance, would render it a very difficult matter for any young man to carry out his education by their aid; at least, to carry it out as far as would, or ought to, satisfy an American. Do not let us be understood as treating lightly the efforts to establish night schools throughout the country. In our large cities they are well attended. We recently witnessed, what we thought a grand sight, a crowd of young men and boys waiting patiently for over one hour to be admitted to the different classes at the Cooper Institute in New York. Such a sight was significant and suggestive. We wish there were more Cooper Institutes throughout both North and South. But we want to show that a mechanic must complete his own education; thousands have done so, and thousands will do so again; and will raise themselves to places of affluence, honor, and influence, by so doing. We maintain that the mechanic in this country has greater scope, more privileges, better pay, more opportunities

than in any other, but with all these we hope to see the institutions for technical education far more numerous than at present, and made attractive and useful to young men. It is a deplorable fact that mechanics in this country, as in Europe, do not pay sufficient attention to their own education. Mechanics have been repeatedly heard to say in some such words as these: "I was educated at the —— school; took so many prizes—a prize for reading, a prize for writing, a prize for mathematics; I graduated, etc., and now I feel competent to enter an engineer's or an architect's office, or to earn three or four dollars a day in a draughting office." We have met frequently with young men who have talked in just such a way as this. Further, we have known young men who, with all their supposed high attainments and knowledge, were successful in obtaining a position such as suited their ambition and self-confidence, but who retired from it, feeling their perfect incapacity to perform any work that could be considered either serviceable or valuable.

The education that a mechanic generally receives begins with the public school or night school; then he is put to a trade; then he is confined to the workshop for ten or more hours a day; then he needs rest, change; then he has no disposition to improve what he has already learned, no inclination to study at home, no ambition to elevate himself by self-culture. This is not an exaggerated statement. Follow the *thousands* of young men from factory, workshop, mill, wareroom and store when their daily employment ends, and how many will you find content to stay at home and improve themselves by good and useful reading, by the study of penmanship, drawing, mechanics, chemistry, or any other science that will help them in the knowledge and the duties of their respective trades and callings. It will readily be allowed that the number who do this are greatly in the minority.

Now self-education is within the reach of every mechanic in this country, and is indispensable for his promotion in society. Going to school will not educate you, going to college will not make you a scholar. Unless there is a disposition to study, a determination to fight against and overcome difficulties, unless self denial and a firm adherence to fixed rules and principles be maintained there will be no progress, and, consequently, no success.

Horace Greeley was a good example of the success obtained by perseverance and industry, and self-culture. He began life as a workingman. As a workingman he found out and experienced the disadvantages of a workingman's position, But he ceased to be a workingman with workingmen only to become a workingman *for* workingmen. Nathaniel P. Banks, once a poor factory boy—from his boyish days, when he worked hard in the factory, rising at early dawn and toiling till evening, "seeing the sun only through the factory windows"—was steadily diligent and energetic. The boy who conned with so much diligence his tasks at spelling or figuring, the boy who amidst poverty and hard work devoted his hours not occupied in the factory to important studies of history and political economy, and the science of government, rose by dint of unwearied exertion to an elevated position as governor of Massachusetts. Who doubts that what has been done can be accomplished again? Are the means for education more limited than formerly? Is talent less appreciated? Are the public slower to award the mechanic, the laboring man, their due? Are theorists and scientific writers predominant, and practitioners lowered in the scale of public estimation and appreciation? Let America's respect for labor, America's encouragement of the arts and sciences, America's sense of justice, America's free institutions, America's advocacy for honest rights answer these interroga-

tions, and we shall find that there is no degree of distinction which may not become the mechanic's if he uses the opportunities and facilities afforded him in this country; that justice will be awarded where merit earns it; that intelligence will be recognized, whether found in the workshop or the study.

In strange contrast to the position held by American mechanics, and the facilities and opportunities they possess for self culture, and promotion and elevation in social circles, we refer to what we witnessed a few years ago in Italy. There the mechanic works from five o'clock in the morning until seven o'clock in the evening, with but half or three-quarters of an hour allowed to eat a scanty meal. His wages in our money amount to about seventy-five cents a day. He is generally ignorant, bereft of all ambition, working merely to gain a pittance which will enable him to eke out a livelihood. He lives in a garret or a cellar, comfortless, too often in the midst of disease and filth, and too often carried to a pauper's grave.

The truth we would impress is that for the full development of the mechanic, or any one intended for professional pursuits in connection with the art of construction, they should rely on their own individual efforts in self-culture and self-improvement as the surest way to success, influence and eminence; and that this country, above all others, affords superior facilities for mechanics to improve and elevate themselves.

LECTURE VII.

Our last lecture was upon the subject of self-education. The present one is a talk on the influence of occupation upon mind.

A few hundred years ago it was a rare thing for a man to select a business or profession for himself. Men generally followed in the footsteps of their forefathers—the son taking up the trade of his father and transmitting it to his children. The son of a shoemaker became a shoemaker; and families existed that had been carpenters for unnumbered generations. If a father was a mechanic it was a matter of course that the sons should follow the same mechanical pursuit. The question as to talent, ability or aptitude was seldom raised; and such was the training of a family that the ambition of the son was generally to succeed his father in business. Even in the learned professions the son of the lawyer or the doctor generally hoped to succeed to his father's business, and this was peculiarly the case amongst the Jews. On the continent of Europe the custom prevails to a large extent, the chief cause being the low price of labor and the difficulty which young men find in obtaining an opportunity to learn a trade. Until quite recently, a comparatively large amount had to be paid in the way of apprentice-fee, and even after that, the apprentice, during several years, had to work for little more than his board and clothes. Our own experience was something of this kind. We were a "premium apprentice" in England. After paying £100 or about $500 at the time of signing indentures which "bound" us for seven years to be a "dutiful and faithful apprentice," we had to work eleven

hours a day, for the first year, without one penny of remuneration, or wages, or reward. The first week's wages in our second year were handled with no little pride, as the first earnings in our life. There was, therefore, a very strong inducement held out to fathers to retain in their own hands the apprentice fee, and the profits of the apprentice's labor, and as the boys had little power of their own in the matter, they had to acquiesce in the best manner they could. We can readily suppose that the result of this would be a class of the most superior workmen. A family that had been carpenters for generations would be very apt to attain special skill, just as we find that the progeny of a good pointer dog are very apt to understand their work almost without being taught. Moreover, certain trade secrets and peculiar methods of working would be handed from father to son more readily than from a master to a stranger lad, and thus a higher degree of perfection would be obtained. The condition of society in this country, and the improvements in machinery that have been made within the last fifty years, have upset this system. There are fewer trade secrets, from the fact that the old trade secrets are of little value; there are fewer special methods of working, because the introduction of machinery has brought about a degree of uniformity in the methods of manipulation that exclude special secret processes; and as labor in this country commands a price far in excess of that accorded to it in the old country, boys find no difficulty in entering our shops and learning a trade, not only without the payment of an apprentice-fee, but with the inducement of wages, even during their apprenticeship, that quite equal the wages of trained workmen in Europe. How different is the system now in this country to that in England one hundred years ago, when old Robert Stephenson, father of the illustrious engineer, George Stephenson, supported a family of six chil-

dren on twelve (English) shillings a week. And yet we are told that young George's highest ambition was to be taken on at the colliery where his father worked. Now young men and even boys in this country become comparatively independent. They are able to fight their own battles; they find that they can maintain themselves comfortably by their own unaided exertions, and they don't feel inclined to be trammeled, even by the wishes and interests of their parents. They therefore choose trades for themselves, and as the young are apt to be dazzled by glittering appearances rather than solid worth, the selections they make are not always the wisest. They are apt to leave the substantial, and in the end the most remunerative trades, and take up with those which seem to be the most respectable, and which promise the most speedy results in the way of fame and fortune. The professions are thus overcrowded, and as a clerkship is supposed to be the easiest door to mercantile pursuits, which are, in their turn, regarded as the most certain roads to fortune, our stores and merchant offices are beleaguered by applicants for positions. All this has been discussed in the public press over and over again, but we do not think sufficient weight has been given to the facts that we have indicated as causing it, and we propose to throw out a few hints that may have some weight in influencing decision about occupation.

While one of the objects of our earthly experience is to procure an honest livelihood and a decent support for those depending upon us, it must not be forgotten that, even so far as mere earthly good is concerned, there are matters of higher import than good drink and clothing, or, in other words, money. Money can do much for us; it can obtain many comforts, and procure for us the *means* of intellectual enjoyment and elevation, but it cannot elevate us intellectually nor enable us to enjoy those things which our minds, from want

of culture or training, are unable to appreciate. The rich man may visit galleries of the most exquisite paintings, he may listen to the most delightful music and sit beneath the teaching of the most earnest philosophers, but all these things, to which his money has procured him free entrance, will fail to afford him a full measure of delight if his intellect has not been cultivated. The painter will sell him his pictures for money, but he cannot sell him ideality wherewith alone these pictures may be appreciated. The muscian will, for a price, discourse to him the most delicious music, but he cannot, for money alone, furnish the ear wherewith to enjoy it; and the philosopher, being probably like most philosophers, poor enough, may be readily hired to lecture upon any given subject, but he cannot furnish for any price that may be named brains to understand his teaching. Money and fame, and even social position, are not the highest good. They sink into comparative worthlessness when placed by the side of that culture of the heart and mind that enables us to appreciate the true, the beautiful and the good. Upon this culture our occupations exert a very notable influence, and we would impress upon the minds of our young men who are about to select an occupation, that *above the question of money, above the matter of fame, above even the important subject of social position, stands the influence of our occupations upon our own minds.*

It is a great mistake to suppose that education for the learned professions confers the largest amount of knowledge and the greatest breadth of intellectual view. There was a time when this was true, but that time has passed away. The education of a young farmer, who has passed through a course of study at one of our agricultural colleges is much more thorough, as far as science is concerned, than that of the doctors of fifty years ago; and this too, in regard to subjects that are supposed to come within the province of medical

men, such as chemistry, botany, etc. The engineer who has fitted himself for his profession at the Massachusetts Institute of Technology, the Sheffield Scientific School at Yale, or the Rensselaer Polytechnic Institute, is or at least ought to be, a more thorough scientist than any lawyer, doctor, or clergyman, from the simple fact that his opportunities have been better. Even the mechanic who has thoroughly prepared himself for his business has obtained more knowledge and has passed through a more thorough course of training than the majority of mere business men.

In the exercise of the different trades and professions the same influence is exerted that was so notable in the preliminary training. Few lawyers possess the same clear-headedness in matters outside legal technicalities that is characteristic of our best engineers. Our ordinary farmers and master mechanics do not perhaps contrast so favorably with the learned professions as we might expect, but this is due to the fact that the men who are now most prominent in these departments are not the men who have had the advantages of what may be called the new education. We feel assured that the young man who seeks the means of the highest development for himself need not feel that he is compelled to enter what are known as the learned professions. That new education which will soon be essential to practical, that is, pecuniary, success, affords means of mental culture quite equal to that offered by the best culture necessary for clergymen, doctors or lawyers, and this is its crowning glory. It is the workers that must be educated if this country is to make anything like respectable progress; it is among these that we must find the general diffusion of knowledge; it is among these we must look for talent and ability, clear-headedness and go-aheadism that will keep parallel with the highest professional skill and learning.

LECTURE VIII.

Our present subject is Adult Education and Mechanics' Institutes.

A few years ago the Head Master of King Edward's School, Birmingham, England, having been requested to distribute the prizes to a number of successful candidates, at a school examination, observing that there were some fifty or more copies of Smiles' "Self-Help" among the prizes, cautioned his audience against being misled by the stirring contents of that book, into supposing that any individual among them, who might be gifted with energy and ability, could therefore have the opportunity of becoming a Watt or a Stephenson. He bade them rather receive and remember this truth, that any workingman who learnt to do his daily laborious task from the highest motives of duty and responsibility, was filling his situation and discharging the purpose of his life as honorably and usefully as though he had attained the eminence of either of those great men.

The idea, though not expressed in so many words, is nevertheless prevalent nowadays, that a workingman has only to obtain an education to make him either a genius or a gentleman. We do not say that all who possess a laudable desire for knowledge entertain this idea, but we do say that it prevails to too great an extent. The object we aim at in quoting the remarks of the Head Master, is to impress upon the minds of workmen the desirability of acquiring, or of seeking to acquire, knowledge for its own sake, for its own intrinsic value, for the pleasure and increased measure of happiness which it is calculated to impart, as well as the in-

crease in value of the man who has obtained it. No one will deny that knowledge is calculated to impart pleasure, and to increase a man's capacity for enjoyment. Much less will any one deny that, in proportion as a skilled mechanic increases his stock of knowledge, he increases his value both to himself and his employer.

We will not stop to enlarge upon what is so frequently brought to the consideration of workingmen in this country by lecturers, reformers and the press—that the means for education are greater, that the chances for position, fortune and influence are more numerous and accessible in this country than in any other. We would call attention to this fact that the means for adult education are, considering the wealth and population of the country, exceedingly few; that in those cities and towns, and manufacturing districts where thousands of workmen are employed, where we should naturally look for and expect to find good family homes, clean, wholesome, and decent, placed so as to receive a full supply of pure air and sunshine; where there should be an organized supply of wholesome, nutritious, cheap food; where there should be leisure for the duties and recreations of family life, for instruction, and for social duties; where there should be systematic, organized teaching, to every skilled workman, of the scientific principles and most improved practice of his trade—it is here, in these very places, that with perhaps a few exceptions, we look in vain for those organizations, means and efforts which should have for their single aim the comforts and rights of workmen. We have a "glorious country" no doubt, glorious in its independence, free institutions, agricultural and mineral wealth; glorious in its rapid progress, its upward tendency in national prosperity, in its arts, sciences and improvements; glorious in its thousands of public schools, in its numerous libraries, museums, exhibitions; glorious in its thousands of

newspapers and periodicals, in its scientific, religious, reformatory and philanthropic institutions, but still with all its possessions, advantages and facilities, with capital and skilled labor—where, we ask, are the organizations, associations and institutes for the education of the masses? where are the technical and industrial schools for adults? where are the mechanics' institutes that should be furnished with such comforts and facilities as to be attractive to workmen and the thousands of young men away from home and home influences?

Mr. Scott Russell, the architect of the Crystal Palace, the Great Eastern, and other large works, said: "While there is no finer breed of workingmen in the world than the British skilled workmen, there is no civilized country in which his interests are so little cared for, and in which the institutions, laws and customs are so unfavorable to his material well-being and to his moral development." This gentleman proposed a "council of skilled workmen," and a "council of legislators," to whom should be referred the discussion of the whole question, and the suggestion of proper remedies. We would like to see "a council of skilled workmen" and "a council of *common sense, non-political* legislators" in every city and manufacturing district in this country that should organize for the social, moral and mental improvement of workmen. London, Liverpool, Manchester, Leeds, Birmingham, Sheffield, Glasgow, Greenock, Dublin, Belfast and other cities and towns in England, Scotland and Ireland, are well known for their great commercial wealth and manufacturing industries; beside these names we can place New York, Philadelphia, Chicago, Boston, Manchester, Lowell, Lawrence, St. Louis and many other manufacturing centres. Now, think for a few minutes of the millions of people employed at these places, think of their multifarious employments, their general social

condition, their productions, their skill and ingenuity, their patient toil, their few comforts, their struggles for a livelihood and health—and say, is there not a great want somewhere? Labor is neither a curse nor a disgrace, but should it be deprived of comforts and means for elevation? Do you ask what elevation? We reply, elevation of body by well-ventilated workrooms and homes, and elevation of mind and soul by the organizations of institutes that shall be, so to speak, the *workman's home and own.*

You point with pride to the colleges, universities, academies, technical institutes, the public and private schools, the industrial schools, the night schools, that are strewed so generally throughout the country. The first indication of progress in civilization is a school. But, again, we ask for the mechanics' institutes, which are attractive to workmen and their sons, as places of amusement, recreation and instruction; where there are classes under practical, competent teachers; libraries of useful and instructive books that are not all novels and romances, and encyclopædias that must not be taken off the premises; where elementary lectures on mechanics, chemistry and scientific subjects are given illustrated with experiments, illustrations on blackboard and charts—made plain and comprehensive, and interesting to men of ordinary culture; where there are first-class concerts and literary entertainments at stated times; where there are apparatus, models, museums, pictures, music rooms—all for the special benefit of workmen. Now, you may say this is all theory and fancy. We have all such facilities in some form or shape; it takes money to do all this; workmen would not attend such places. All efforts in the organization of such places would be futile. Workmen, as a general thing, would rather attend theatres and ball-rooms, and lager-bier saloons, and the lower orders of sensual amuse-

ments, than frequent Mechanics' Institutes. If a man, fond of flowers, has nothing but a back yard to walk in when he gets home from his daily employment, don't be surprised if some day you find a neatly-painted box there, from the contents of which are springing up flowers and vines of graceful form and beautiful color. Give that man a garden of his own; he will dress it and keep it. Now, as a general thing, the intelligent workman has no attractive institute of his own; but give him one, and he will help it and take pride in it, and mechanics' institutes shall stand among the grandest institutions in the country.

LECTURE IX.

Next in importance to the moral and religious training of young men come their scholastic learning and honorable occupation. That occupation is sometimes selected by parents or guardians, more frequently by young men themselves. To-day we find a great diversity of opinion about studying for a profession and learning a trade on the side of the former, and many mistakes from a lack of good judgment and wisdom on the part of the latter. The selection of a business or a profession to which a whole life is to be devoted demands carefulness, honesty and the best of judgment. There is no denying that gross blunders and egregious errors occur daily by having wrong men in the wrong place—and we may add by the removal of right men into a wrong place. Capacity and competency combined with faithfulness, firmness and honesty are what are wanted in the business and professional life of this fast age. Let us talk plainly for a few moments. Parents mistake propensities and likings for particular things in their children for talents. A boy is fond of imitating, mimicking, caricaturing and reciting, and goes to sleep with Shakespeare in his hand, replies dramatically to ordinary questions, gets posted on Kemble, Macready, Forrest and Booth, when lo! his parents and relatives baptize him as a "natural actor," and he is rushed for the stage. But the requirements and study and hard work don't suit him, so he tries his hand at something else. A boy likes to look at locomotives and steamships and moving machinery—these interest and amuse him, and lo! his father says "Stephen will make a splendid mechanic," and convinces

the boy that he inherited mechanical talent, and comforts himself that the world will be improved by the development of his son's remarkable mechanical abilities. But, as time wears on, the machinist business has no charms for the youth, and the disappointed father lets him go into warerooms as salesman or on the road to sell a patent clothes-wringer. We might enumerate many such instances, but there is no gentleman in this audience who is not familiar with such instances of mis-conceived ability. A youth may like a great many things, just the same as you and I like a great many things. We used to sit for hours in English criminal courts, spend our half-holidays there, among gowned and wigged barristers, lawyers and witnesses, on purpose to hear Alexander Coleridge and Cresswell Cresswell address my lud and jury, but there was no law that *I* should, necessarily, become a lawyer. Again, it will be allowed that the professions have been held up to many as the most desirable for attainment. D.D., M.A., B.A., M.D., are easily written after a man's name. They are, by no means, indicative of great scholarship, great talents, or large income.

> **"Is learning your ambition, there is no royal road,**
> **Alike the peer and peasant, must climb to its abode.**
> **Who feels the thirst for knowledge, if Helicon may slake it,**
> **Must say, with Roman firmness, I'll find a way or make it."**

Without argument, let us allow that there has been in this, and other countries, silly prejudices against handicraft. A feeling among all classes that it was better to be a clerk than a mechanic, more desirable to be a lawyer than a master machinist, still better to be a doctor than a carpenter, and so on all the way through, and that the professions have been sought for in preference to industrial pursuits, regardless of ability, talent, or capacity.

Referring to the recent inauguration of a class in the

science of plumbing, under the auspices of the Metropolitan Museum of Art, New York, a correspondent of the Philadelphia *Record* says: "If this will diminish the number of young men whose highest ambition seems to be to stand behind the counter and wear good clothes, it will be a public benefaction. There's a great deal of money in trades, and very little in counter jumping, and yet only one young man in a hundred is willing to blacken his hands wlth tools. It is not always the boy's fault, however. A gentleman of my acquaintance, who is a broker in Exchange Place, said to me recently: 'I ought to have been a machinist; I would have been rich by this time. When I was a boy I wanted to go into the Allaire Works, but my father was afraid it would soil my hands. He wanted me to be a gentleman. The result is that I have never liked my business, and never made more than a living at it. Had he let me go in as an apprentice in the machinist trade I would have been building engines and coining money by this time, and my whole heart would have been in it.' The fathers of to-day in New York are the same. They would almost as soon bury their sons as make them apprentices. The result is a race of mediocre clerks and book-keepers, who part their hair in the middle, smoke cigarettes of paper, and find their intellectual level in the flash newspaper of the day."

How has it been with other nations? The Jews had none of those silly prejudices against handicraft, as mean and contemptible, which were felt by the Romans and Greeks, who left mechanical pursuits to their slaves. They, in their wisdom, required that every boy, whatever his rank, should learn a trade. The good of the child required this, no less than the good of the commonwealth, so that no healthy man should eat his bread till he had earned it by his labor. Some particular traders were regarded as more or

less disreputable, and men who followed them could not be high priests or kings. But be it remembered that men who filled the highest callings amongst the Jews were skilled workmen in various branches of secular industry. In the days of Christ, as well as before and after, rabbis held in high honor were taken from amongst millers, bakers, builders, carpenters, smiths, shoemakers, surveyors, money-changers, tanners, and various kindred vocations. Some, after they became rabbis, spent one-third of the day in study, one-third in manual labor, and one-third in prayer. When Phinehas was chosen as high-priest he was working as a mason; Johanan, the president of the Sanhedrim, was a merchant; Ismael was a needle-maker; Menahem was a baker; and Simon was a weaver, all holding high positions in Judaism. Just as in Christianity, Jesus was a carpenter, Peter and John were fishermen, Matthew was a collector of taxes, Luke a physician, and Paul a tent-maker. But all uneducated artisans were held at a discount. Honor, in the Jewish mind, associated itself with handicraft and study. The highest teachers held that while the knowledge of a trade without study was vulgar, study without a trade was dangerous; but taken together they kept away sin and lifted a man above all ignoble idleness and dependence. Hence, when the parents of Jesus put Him to the occupation of Carpenter, making Him dependent for his daily bread upon the skill of his labor, they were only doing the best and noblest thing for the youth, according to the high civilization of their nation and times. There was much of man's work which you could not set to music till you heard the song of the axe and hammer from the carpenter's bench at Nazareth. He taught a truth that every form of honorable industry is hallowed and dignified. Passing from those times to more recent years, we find noble examples that have been living props of the dignity of labor.

We do not to-day think less of Gutenberg, Franklin, Fulton, Rittenhouse, Watt, Stephenson, Brunel, Sir Richard Arkwright, Sam Compton Chantry, Alexander Murray, William Cobbett, Elihu Burrit, Horace Greeley, Nathaniel P. Banks, Abraham Lincoln, Ulysses S. Grant, William Lloyd Garrison, Henry Wilson, and a host of others who have been prominently before the world's eye and criticism, because they in early life struggled with poverty and difficulties and worked at manual labor.

Some of these men have let us see the sun through the factory windows. The midnight oil which was consumed in their self-culture and study; the dust and smoke of their workshops, their musings as well as their immense conflicts, have proclaimed to the world that there is no necessary connection between manual labor and degradation, no essential disjunction of the work of the hands from that of the head, that there is no law of nature which makes impossible or even difficult, an alliance of good manners, high morals and elegant accomplishments with the active duties of a mechanic. Hear it young men. There is no one good quality of the gentleman which can sit ill on the mechanic however poor he may be. Said our own Franklin, "He that hath a trade hath an estate; and he that hath a calling hath a place of profit and honor. A ploughman on his legs is higher than a gentleman on his knees."

But we must draw nearer to the centre of our subject, "Learning a Trade." The object of the remarks that have been made is to show that in the selection of any honorable occupation, any trade demanding manual labor and the exercise of both muscle and brain, no one should approach it with any foolish ideas about degradation, inferiority, unmanliness, or even erroneous supposition that the studies of law, divinity, medicine, finance or the fine arts are more essential

and beneficial than mechanism, invention, manufactures and the industrial arts.

This matter of learning a trade is an important one, not only to the individuals immediately concerned, but to the prosperity of commercial and industrial enterprise. The great object in view is to obtain skilled artisans. In obtaining these we get superior workmanship, improvements in manufactures, new and valuable inventions, and rapid advancement in the manipulation and construction of materials. In all civilized countries, competition is so earnest and extensive that the very best manual dexterity and skilled labor are absolutely demanded. The question comes up, how are these to be obtained and maintained, to ensure the best results? This is the inquiry to-day. Manufacturers are interested in it. The press is bringing it to public notice and consideration. The country is experiencing a return of commercial prosperity. Our manufactories and workshops are full of work and workmen. Immigration is enormous. The call to-day is not for capital but skilled labor. We shall make slow progress if the young men of this generation have not been trained to the realization of the dignity of labor, if they are not put into the possession of facilities and given incentives for learning a trade. The small compensation, the drudgery, the indifference on the part of employés, the opposition by journeymen, the long hours, the hard work, the struggle for self-support and maintainance of relatives are among the drawbacks which make young men say "All these things are against me." There is need, then, at the present time, for a revival of the apprentice system—modified and improved, and rendered suitable for the requirements of the future. The old English system is divided. There are premium apprentices and common apprentices. The premium apprentice has to pay a fee at the time of signing indentures, and is bound

to stay with his employer for a term varying from three to seven—usually five—years. When a youth, I was ambitious to be trained for a minister in the Church of England, but my father, at that time one of the principal ship chandlers, rope and chain makers in Liverpool, and known as one of Nature's noblemen in Christian conduct and benevolence, said to me, "Tom, I am going to give you something better than money, something that no one can take from you, something by which you can always get a living, and that something is a trade. You had much better be a good mechanic than a poor parson." He bound me apprentice for five years in one of the largest machine shops in Leeds; paid a premium of £100 ($500), and supported me in board, clothes and all expenses until I became twenty-one years of age. I worked in the machine shop from six o'clock in the morning until half-past four in the afternoon; and worked in the drawing office from five until seven in the evening. I got no wages during the first year, the second year I received five shillings per week, and the last year twelve shillings per week. My father then put me into a large locomotive shop, and I got one pound per week; then he sent me to sea as a supernumerary engineer without pay, then as third, second and chief engineer, on pay. He lies sleeping beneath the churchyard sod, but I, his youngest son, with all my vicissitudes, mishaps, and misfortunes, can testify to-night that the good old man was right when he said, "I will give you something better than money, something that no one can take away from you—and that something is a trade." For thirty years in this country I have never been a fortnight out of employment in some capacity, acquired from experience in the workshop and the draughting office.

Now the English ordinary apprentice has no privileges beyond working in the shop. He is taught amid a great deal

of drudgery, and too often rough usage. He becomes a good or an inferior workman, according to his abilities and application. He seldom looks beyond the shop. He is a workman, and always expects to be a workman. He may become a job hand, a foreman, a superintendent, but his chances for promotion are few and far between. Again, in many cases, he is confined to some particular branch, some special operation. A young man in this country has far greater facilities for learning a trade than in some others.

We submit for discussion the policy of premium apprenticeship. It works well, we remark, where parents or guardians are in circumstances to pay a premium and give facilities for technical education, where a young man is independent of any allowance in the form of wages from his employer; but the youth without such advantages, with an ordinary school education, looks for immediate compensation. "How much can I *earn?*" not "How much can I *learn?*" is, nine cases out of ten, the first consideration. He looks for and selects, or his parents for him, an occupation at which he can realize some pay at once, without much inquiry as to ability or his likelihood for success. One of our industrial journals, in speaking of the "Decay of Apprenticeship," states: "There are in this country now hardly any apprentices, properly so called, and we are, therefore, as to the future, deprived of the means by which skilled artisans have been made in the past.

"What is to be done in this emergency? Some remedy must be found; and, of course, a remedy will ultimately be found; but the problem is a difficult one, and it is not improbable that trouble may come in its solution. It would seem that a government (that is, with us, a people) that could undertake a task not only of educating all of its citizens, but of compelling them to receive education, might find in the

social and political necessities of this case a justification for supplying the means of instruction in the various arts and crafts which are suffering, and which seem destined to suffer more hereafter, from the disuse of apprenticeship. Nothing, indeed, can supply the place of real apprenticeship. There is no teaching like that which passes from hand to hand, from eye to eye, while practice illustrates what is inculcated by precept. And in all arts there is something, and something of the highest value, which is gained by absorption in the very atmosphere of the workshop of a master workman in his craft, who himself acquired his skill amid similar surroundings. There are traditions in all arts which do not take form in words."

Another industrial journal informs us that the Ames Manufacturing Company, of Chicopee, Mass., are doing something toward a return to the old apprentice system. "The company have been very much troubled to get skilled help, and also by having men leave after they have learned enough to begin to be useful. They have now adopted a plan something like the former system, only the term of service is not more than three or four years, instead of seven, and they are overwhelmed with applications. The men sign a contract to stay to the end of the term, and the company will teach them the different branches of the business, so that when they go out they will be masters of the trade, instead of knowing how to run but one machine, or how to do one particular kind of work. The company keep ten cents a day from their pay until it amounts to $100, which is given to them at the end of their apprenticeship."

A system of apprenticeship in some respects new, has been adopted by Messrs. Richards & Dole, machinists, of Springfield, Mass. It is intended to combine the thoroughly practical education of the shop with the theoretical education of

the school; or, in other words, it is an industrial school in which the most time will be given to practice, instead of theory. They propose to require of the apprentice fifty-eight hours a week of work in the shop, and nine hours of study. The term of apprenticeship for those beginning to learn a trade, who are under twenty years of age, is to be six years, in which time, under this system, it is believed an apprentice will be qualified to rank with the best journeyman, and to earn the same wages. Those who are over twenty years of age are allowed to finish their apprenticeship in five years, and those who have worked in a shop are advanced according to proficiency. The beginner is first put to drawing from sketches, and then takes up projection and diagrams, and advances regularly according to his ability. It is believed that in this way one year will qualify him as well to work from drawing as four or five years ordinarily. All applicants are taken for from four to twelve weeks on trial, and if not satisfactory are then dismissed. For the first year's labor 5 cents per hour is paid to those under eighteen, 6 cents to those who are eighteen, and 7 cents to those who are twenty and upwards; for the next years the rates are advanced to 6, 8, 10, 11 and 12 cents. The firm also pay 2 cents per hour additional into a reserve, which is paid to those apprentices who finish their full term of service; for the six years this amounts to $400.

The scheme in this shop grew out of the difficulty experienced in getting thoroughly qualified machinists, and is an attempt to solve again the old problem of how to continue the system of apprenticeship, now largely fallen into disuse. It is stated that this firm already have more applicants than they can accept. The scheme certainly seems worthy of a trial. We have but little sympathy, in many cases, with the lament over the decadence of the apprentice system. The

introduction of machinery, and the consequent sub-division of labor, have made it unnecessary in many trades. In some trades, however, there cannot be such a sub-division nor such machinery as will do away with the necessity for a large proportion of skilled, thoroughly educated mechanics, and the machinist's trade is one of these. The scheme we have described above certainly seems well calculated to produce workmen not only competent for the ordinary routine of shop work, but competent to design and oversee the execution of work.

In machine shops and foundries in St. Louis, the rates of wages for apprentices vary from $2.50 to $3.50 per week during the first year of apprenticeship, advancing by graduations to from $5 to $6 per week in the last year. Apprentices are not taken who will not agree to be bound for at least four years, the preference being given to those who are to serve five years; in other words, youths must not be over 17 years of age when entered, those not over 16 being preferred. While the rates of pay quoted are the usual ones, exceptions are made in favor of those who exhibit high intelligence and faithfulness; those who are found deficient in these requisites being allowed to leave and seek employment elsewhere.

Now it matters not whether a young man is put apprentice to a bricklayer, a stone-mason, a carpenter, a machinist, a printer, an engraver or a book-binder; there are obligations on both sides. The one is to teach, the other to learn and make himself valuable in faithful service. We are of the opinion that when a young man enters on learning a trade there is very much dependent on his own exertions and interest in it. The great helps of technical schools, libraries, valuable industrial journals and publications, teachers and personal observation are all his own. He can avail himself of them all or not. The facilities for self-culture and mental

improvement are to be had in our large cities, and young men are almost without excuse if they do not appreciate and avail themselves of such means, remembering that it is the brain and skill of men which transform rude and cheap materials into beautiful and valuable articles of manufacture. What we need to-day is a greater number of technical and industrial schools. Young Americans will cease to have the idea that the prizes of life are all to be found in professional or mercantile circles, or in the business departments of manufacturing concerns, when technical and industrial schools and institutes abound as means for training the intellect in the direction of mechanical, manufacturing and engineering knowledge. We want more manual training schools, more technical institutes like those at St. Louis, Worcester and Boston. We are talking for them. We shall get them. Here is a sketch of the one opened at St. Louis, named the Manual Training School of the Washington University, the object of which is, besides instruction in what are known as a high school course of study, the teaching of practical carpentry, wood-turning, pattern-making, iron clipping and filing, forge work, brazing and soldering, the use of machine shop tools and such other instruction of similar character as it may be deemed advisable to add from time to time. The course of instruction covers three years. Special attention is paid to both free hand and mechanical drawing, in connection with which instruction is imparted in the nature, theory and use of tools. The carpenter shop of the school is furnished with benches for twenty workmen, and contains grindstones, circular saws and a scroll saw for general use. The pattern shop now has nine and will soon have sixteen speed lathes, driven by steam, fitted for all kinds of light wood-turning. The blacksmith shop is fitted with eight forges, anvils, and full sets of tools. Students are here taught the art of drawing, bending, upsetting, welding

and punching of both iron and steel, and the making and tempering of steel tools. The machine shop contains a first-class Corliss steam engine, the cylinder of which is 14x42 inches. There are six engine lathes, a planer, an upright drill and a gear-cutter. All the shops and other rooms are spacious and well lighted, warmed and ventilated.

This school, under the supervision of William G. Eliot, Chancellor of Washington University, and C. M. Woodward, director, was opened September 6, 1880, when but a single class was admitted. The capacity of the school is to accommodate and educate about 150 pupils. Sixty or seventy new pupils forming a new class, will be admitted next September.

In summing up, we submit, first, that sound judgment should be exercised by parents and young men in the selection of a trade agreeable to taste and suitable for different abilities. If a boy has a "mechanical turn," likes mechanics, studies them, displays ingenuity and skill in little things, the probabilities are, other things being equal, that he will succeed in some mechanical employment. Second—That discrimination is necessary not to mistake propensities and likings for genius or extraordinary talent. Third—The dignity of manual as well as of mental labor should be taught and recognized. Fourth—The apprentice system should be revived with certain modifications. Fifth—That supplementary to, but essential for the learning of a trade, the apprentice should have the advantages of a technical education and manual training. Sixth—That those apprentices whose means will not allow them to pay for technical education by day study, should have access to free industrial and technical evening schools.

Said Mr. John S. Clark in a lecture on Industrial Education at Boston, Mass.: "The statement is too true that we have no educated American mechanics. No provision seems to have been made in our system for the education of mechanics.

In the furniture factory of Bradbrook & Co. only four of the fifty cabinet-makers are Americans; three of the four are employed on an inferior grade of work, and the other confesses his inferiority to the foreigners. The same fact is true of Geldowsky's workmen, and out of Paine's 160 men only 16 are Americans. The trouble is that Americans cannot work from drawings. Nearly every workshop in the country witnesses the degradation to which Americans are subjected. The only way in which Massachusetts can protect the interests of the people is by cultivating the application of brain-power to her industrial education. The best brain-power of Massachusetts has for years been steadily working away from her, leaving foreigners in its place." Mr. Clark closed with an appeal, as we do now, for a wider, more thorough industrial education. Germany sets us an example, Austria and England are awakening to the need of a more general education, and America, if she is to hold her own as the great manufactory and workshop of the world, must educate her artisans at least up to the mark of her rivals, if not higher. It is to colleges of science applied to industry that we must look to enable us to accomplish these important objects. The prophecy of Daniel is fulfilled this day before our eyes. We see that many run to and fro, and that knowledge is increased. We see, to speak commercially, capital judiciously invested and labor rightly directed. We see man's condition, as a social being, improving; man's intelligence progressing; we see man's ingenuity in its grandeur; man's skill in proficiency; man's industry rewarded; man's enterprise successful; man's tastes consummated. We see mechanics and artificers free from monarchial or aristocratic tyranny, and industrious because they are free—free to speak, free to invent, free to act, free to push forward on the track of industry, urged on by the power which a mighty nation recognizes in the progress of the arts and sciences.

LECTURE X.

The object of this paper is to show the need of Mechanics' Institutes, and the possibilities for the more general establishment of them in this country, by the united efforts of American manufacturers and artisans.

The great need of Mechanics' Institutes, or institutions where mechanics and artisans may get specific and practical knowledge relating to their employment, is commented upon, just now, by several of our leading daily newspapers. Not many days ago the Brooklyn *Eagle* published an able and practical talk upon the subject of an institute being founded in Brooklyn, in character, system, tone and conduct similar to the well-known Cooper Institute of New York City. The New York *Sun*, of August 6, takes up the matter of industrial schools for journeymen and apprentices, and, in an editorial, under the caption of "A Just Criticism," alludes to the fact of Chinese students being recalled from this country, because, in the opinion of the ambassador who examined into their progress, they are not likely to obtain in our scientific schools and colleges the practical industrial education their Government desires for them. "What the Government at Pekin wants is that they shall carry away with them a knowledge of our industrial arts, of mechanics and engineering, so that they shall be able to assist in developing the resources of China after the modern methods which have been so successful in the West."

We have, undoubtedly, a few very excellent institutions in this country, where young men can become practical workers as well as good thinkers. Schools, colleges, universities, tech-

nical institutes, and all similar means and facilities for education, can not supply brains. Those who "graduate" from an institute of technology must be living examples of the thoroughly practical and useful knowledge that can be gained at such institutions. With such shining light before them, young men would certainly know that all talent and smartness are not confined to commercial and financial circles. We can not get behind the fact that the sons of the wealthy, and of even the "well to do" evince a dislike for industrial training. Learning a profession may save them from the superficial smattering got at public schools, and the pursuit of money may give them a stimulus for work which they never found in the college course. "But," adds the *Sun*, "in this country great numbers of young men are every year sent out by the four hundred colleges of which we boast, almost as helpless, so far as earning their livelihood is concerned, as the waifs in a foundling asylum. They become a charge to their friends, are seriously injured as practical workers by their flimsy education, are unable to find places in which they will fit, or have acquired finical notions regarding their proper sphere which make them obnoxious to employers. Their heads may be as soft as their hands."

Where there are manufactories, work-shops and mills, there will be mechanics and artisans, as a general thing, not without exceptions, who are not only willing but anxious to avail themselves of any substantial means for their education. And we advocate a Mechanics' Institute in every manufacturing city, to be organized, maintained and supported in the main by the resident mechanics and their families.

Public opinion is evidently awakening to the fact that if we are to compete on fair terms with other nations we must put more science into our industries, and substitute the rule of **brain for the rule of thumb.** It is gratifying to find that so

many acknowledge the importance of technical instruction; it is also gratifying to note the means that have been put into successful operation for the more general diffusion of science and industrial art. But there is much confusion, as it seems to me, in the minds of many who speak on technical education as to the real meaning of the term. Some seem to look upon any form of science instruction, however elementary, as technical education. This is wrong. Technical education does not consist in merely giving instruction in the principles upon which certain work is performed. This is only one step, although a very important one. There must be added further instruction in the working details that will allow of the work being performed successfully. Technical education means instruction in everything that gives power to do—use of knowledge, exercise of eyes and hands, and all powers of mind and body together that can put any kind of work into shape. In the matter of general education we are foremost among the nations. Our public schools, however inefficient they appear at times and in certain localities, as part of a national system are among our best developments. The fact that in this land every child holds the possibilities of acquiring, at least, a knowledge of the *three R's*—reading, writing and arithmetic—just as soon as he can spell or count, is of itself a grand one. Who can estimate the influence and usefulness of public schools? They may be deficient in many particulars; systems may be faulty; teachers may be incompetent in aptitude as teachers; buildings may be badly planned, poorly constructed, badly ventilated, but they are schools, free schools—free to all, open to all—monuments to progress and civilization. But these primary schools must be supplemented by technical schools and mechanics' institutes. The technical schools should afford every opportunity for noting every set of circumstances under which manufacturing,

chemical and mechanical operations can be conducted. Provision should be made for the chemical and mechanical testing of all materials used in the various manufactures and trades, and for the careful comparison of one description of material with another; and modes of shaping and putting together should be not only explained but put into actual operation. I maintain that a youth or man who has passed through a technical school should not only have his mind well filled with all science and general information bearing upon the occupation he is about to engage in, but also have his eyes and hands so trained that he can use his tools and shape his materials so as to bring his work quickly to a successful issue.

Now, taking into consideration the vastness and *fastness* of this country, its wealth, its free institutions, its millions of intelligent mechanics and industrious artisans, its unprecedented progress in invention and the industrial arts, the general desire for knowledge and useful information—I inquire, are we not, as a nation, behind others in furnishing means and facilities for the technical education of our industrial classes? Where are our evening schools, at which a mechanic, after his daily employment, can receive thorough, comprehensive practical instruction in those branches of science that relate to his trade or employment? Such an educational resort that he will attend with pleasure and profit to himself, one that is attractive, pleasant and agreeable in its surroundings, where books, charts, maps, apparatus, drawings, models are his for examination and consultation, where familiar talks and lectures on science, concerts, exhibitions and explanation of inventions, are given to interest and amuse him? You will, perhaps, point me to such institutions as the Massachusetts Institute of Technology, with its school of mechanic arts, its school of practical design, its free courses of instruction and its society

of arts, its faculty of Ph. D., LL. D., A. M., S. B., C. E., etc., its provision of scientific and literary studies and practical exercises, embracing pure and applied mathematics, the physical and natural sciences with their applications, drawing, the English language, history and political economy, French and German, chemistry, building and architecture, metallurgy, geology and mining; or to the Stevens' Institute of Technology, a school of mechanical engineering; or to the Worcester Free Institute; or to our well known Cooper Institute, efficient, popular and democratic in all its features; or to the Cincinnati School of Design; the Columbia College and its School of Mines, to the numerous schools of science and polytechnic institutes, and pointing to these, noble and grand as they are in aim, practice and efficiency, you cannot say to the mechanics, artisans and workmen—" these be thy Gods, O! Israel," and why? Why do not these institutions meet the want we experience to-day? because they are not as I would have the term plainly and strictly understood—mechanics' institutes. I make a great distinction between an Institute which requires a certain amount of educational preparation and money before you can enter it, leaving out respectability and social standing, and one with its doors ever open to workmen and workmen's sons. No one appreciates or estimates more highly than I do such institutions as I have mentioned and alluded to, and do not misunderstand me on this point, they need no commendation from me; they are noble institutions, well equipped, doing good work; they are grand monuments of honor to their founders and incorporators, they fill their mission, not that I think of them less, but we need something more.

Look at Brooklyn, with its population of 500,000. Can you take me some evening when its 10,000 mechanics have finished their day's work to the Brooklyn Mechanics' In-

stitute, where we may find at least 1,000 out of the 10,000 engaged in the studies of mechanical drawing, chemistry, or even writing and arithmetic? What is there in that city for these men? churches, business colleges, and Young Men's Christian Associations, but no mechanics' institutes. Shall I name such manufacturing cities as Lowell, Lawrence, Manchester, and still ask for mechanics' institutes? Shall I look to the West or to the South for practical efforts and schemes having the sole object in view—the education of mechanics and artisans? Quite easy to get a public school education, quite easy to select and learn a trade, not quite so easy to add to that learning a knowledge of its fundamental principles; quite easy to forget what has been already taught or once acquired; not quite so easy to get a special training for a special pursuit.

Here then, I take my stand. Public and private day and evening schools have their special sphere of usefulness. Technical institutes, as they are, have theirs, and have possibilities for increased usefulness. Mechanics' institutes, in the true sense of the word, are very few and deficient; public opinion is awakening to the want. Constant discussion and practical schemes for the organization, government and maintenance of mechanics' institutes, therefore, are and always will be in order so long as we have any workmen to educate.

It is in the power of any body of artisans to organize and maintain their own mechanics' institute. This is an assertion. It may be called only visionary in conception, a theory that will not bear a practical test. Let us go somewhat into details, and examine if there is any practical foundation to build upon.

Here is a city in which there are 10,000 artisans, men employed in different pursuits and occupations; as machinists, engineers, blacksmiths, pattern makers, carpenters, furniture

makers, dyers, shoemakers, etc., etc. Each of these is able to contribute two dollars a year, or his employer or friend will subscribe for him. We have, then, $20,000 per annum.

Rent of building, ...	$4,000
Fuel, gas, water, janitor, . . .	2,000
Printing and stationery, . . .	200
Books, newspapers, monthlies, .	1,000
Librarian, teachers and lecturers, .	4,000
Models, apparatus and furniture, .	2,800
	$14,000
Balance unexpended . .	6,000
	$20,000

What artisans and mechanics can do to build up such an institute, and make it popular and attractive, is something enormous. Let each one give a book once a year and we get 10,000 books the first year, 20,000 books in two years, 50,000 books in five years.

Let 5,000 mechanics each make, with his own hands, a model of something he may be interested in—a working model of a steam engine, locomotive, boiler, improved furniture, inventions and devices of his own—and we get 5,000 models for illustration and explanation, and specimens of handicraft.

Let there be an industrial museum and model-room, open for the reception of appropriate gifts, and it would be stocked in one year's time.

Let lectures—plain, simple, scientific—be given on chemistry, electricity, magnetism, astronomy, mechanics, etc., by good talkers and instructors, and the hall will be regularly filled.

Now, this and much more can all be done by working men

themselves, under the guidance of sound common sense and interested intelligence. But what employer or business man, with a spark of philanthropy and generosity, would not lend a hand and help those who endeavor to help themselves to become more useful citizens?

It is quite reasonable to expect that men of means would aid such enterprises, and that manufacturers would give their assistance in money, gifts and influence.

Do not suppose that such institutes would be of an exclusive order. The great mechanics' institutes of Liverpool, London, Manchester and Leeds in England are not exclusive when you can find audiences over one thousand in number and large halls filled to repletion on lecture occasions. At the Leeds Mechanics' Institute it was my privilege to hear lectures by Sir William Fairbairn on steam and the steam engine, and these and other like lectures were always listened to with apparently intense interest by large audiences of men and women.

A small annual fee enabled a youth or an adult to attend classes, hear lectures and enjoy occasionally a first-class concert. A member's ticket entitled the holder to all the benefits offered, and the institute was open during both the day and the evening to both sexes. The aim of English and German technical education is thoroughness. Here we are said to be too superficial, too fond of "cramming," too anxious to "graduate." The subjects of primary importance for study at mechanics' institutes should be arithmetic, penmanship, geometry, algebra, the principles of mechanics, geometrical and decorative drawing, mensuration, chemistry and experimental philosophy, practical mechanics, civil, mechanical and mining engineering. Models, charts and apparatus should be accessible to students, and of primary importance, there should be teachers qualified to teach clearly and com-

prehensively. I remember that among the branches taught at the Liverpool Mechanics' Institute were marine architecture, ship-building and navigation. For these there was a large rectangular room, in the middle of which stood a water tank some forty feet in length, in which were complete models from an ordinary canal boat up to a full rigged bark and steamship; there were paddle wheels and screw propellers, steering wheels and numerous nautical appliances. Around the room there were charts, colored and plain, diagrams and pictures illustrating the principles of ship building. I observed in different parts of this room, models suitably and neatly mounted, each bearing a label like this: "Model for an ocean steamer, designed and constructed by Frank Jones, 14 Catharine Street, Liverpool, age eighteen, after two years study at this institute." Every department was as complete as this, and the teacher had all facilities for explanation and exemplification. *That I call practical education.* Again, permit me to remind you I do not forget that such system exists in some of our technical institutes, but I remind you that it is very far indeed from being general, and not often available to the working apprentice and artisan.

I should very much like to see twelve or more members of the Polytechnic Association of the American Institute start a New York Mechanics' Institute on the basis already referred to. It would be an unqualified success. There are money and brains and interest and need enough for it. Once established, other cities and towns would follow the example, and who can tell the mighty influence and usefulness that would result from such enterprises.

To our public institutions of a sanitary and reformatory character, to our public and private schools, to our technical institutes, colleges and universities of learning, to our host of political, religious, social, scientific, literary, musical, medical,

mercantile and charitable societies, let us add mechanics' institutes. Our country will grow faster and better with them; our inventive and mechanical genius shall be more largely developed, the self respect of the artisan shall be increased, his manhood asserted, and his intelligence acknowledged and felt. No man knows the powers of his own mind until they have been exercised. Thousands may have gone down into obscure graves in whose soul the living fire of poetry, or the bright sparks of genius lay hidden and lost. And in the corner of many a sacred spot may repose the mortal tenement from which the soul of an Arkwright, a Fulton, a Watt or a Davy may have fled, which merely wanted education to make it spread a lustre over industry and science. The most apparently illiterate may have natural powers unknown to themselves, for as expressed by the poet in language not more beautiful than true:—

> "Full many a gem, of purest ray serene,
> The dark, unfathomed caves of ocean bear:
> Full many a flower is born to blush unseen,
> And waste its sweetness on the desert air."

APPENDIX.

ON PLANE METALLIC SURFACES, OR TRUE PLANES.

AND OTHER PAPERS.

BY SIR JOSEPH WHITWORTH, F.R.S.

OF PLANE METALLIC SURFACES, OR TRUE PLANES.

The method hitherto adopted * in getting up plane surfaces has been (after filing to the straight edge) to grind them together, with emery. In some cases it has been customary to try them previously on a surface plate, and to go over them with the scraping instrument; but they have always been ground afterward. The surface plate itself has been invariably treated in the same manner.† The process of grinding is,

* That is, prior to the year 1840.

† Surface plates consist (as is well known to those familiar with our workshops) of iron plates, strengthened by ribs on their backs, and having their faces as smooth and as true as possible. They are used for the purpose of testing and correcting any surfaces which are required to be made true. A straight edge is also used for testing the truth of surfaces; it is generally so called when its surface is very narrow as compared with its length, being usually the side face of a long flat bar. Surface plates are made of various sizes.

A simple and interesting experiment may be tried with a pair of true surface plates. If one of them be allowed to slide on the other so as to exclude the air, the two plates are caused to adhere together with considerable force, by the pressure of the atmosphere. The surfaces should be well rubbed previously, with a dry cloth, till they are perfectly free from moisture, that the experiment may afford a fair test of accuracy. If any moisture be present it will act like glue, and cause adhesion to take place, supposing the surfaces to be much inferior. But if they be perfectly dry, adhesion proves a high degree of truth, rarely attained.

The experiment may be varied, by letting one surface descend slowly on the other, and thus allowing a stratum of air to form between them. Before they come into contact, the upper plate will

in fact, regarded as indispensable wherever truth is required, yet that of scraping is calculated to produce a higher degree of truth than has ever been attained by grinding. In reference to both processes a great degree of misconception prevails, the effect of which is materially to retard the progress of improvement, and which it is of great importance to remove. While grinding is universally regarded as indispensable to a finished surface, it is, in fact, positively detrimental. On the other hand, the operation of scraping, hitherto so much neglected, constitutes the only certain means we possess for the attainment of accuracy. A few remarks will clearly illustrate the truth of this statement.

It is required, in a plane surface for mechanical purposes, that all the bearing points should be in the same plane,— that they should be at equal distances from one another,— and that they should be sufficiently numerous for the particular application intended. Where surfaces remain fixed together, the bearing points may, without disadvantage be fewer in number, and, consequently, wider apart; but, in the case of sliding surfaces, the points should be numerous and close together.

A little consideration will make it evident that these conditions cannot be obtained by the process of grinding. And,

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become buoyant, and will float on the air without support from the hand. This remarkable effect would seem to depend on the close approximation of the two surfaces at all points, without contact in any—a condition which could not be obtained without extreme accuracy in both. The escape of the remaining portion of air is retarded by friction against the surfaces, the force of which nearly balances the pressure of the upper plate. If one end of the upper plate be slightly raised, and allowed to fall suddenly, the intervening air will act like a cushion, causing a muffled sound to be emitted, quite different from that usually produced by the concussion of metallic bodies.

first, with regard to general outline, how is the original error to be got rid of? Let it be supposed that one of the surfaces is concave, and the other a true plane. The tendency of grinding, no doubt, will be to reduce the error of the former, but the opposite error will, at the same time, be created in the true surface. The only case in which an original error could be extirpated, would be, when it was met by a corresponding error, of exactly the same amount, in the opposed surface, and the one destroyed the other. But it is evident, that where only two surfaces are concerned, the variety of error in the general outline is not sufficient to afford any probability of mutual compensation.

It will further appear, that if the original error be inconsiderable, the surfaces must lose instead of gaining truth. It results from the nature of the process that certain parts are acted upon for a longer time than others. They are consequently more worn, and the surfaces are made hollow. Nor is there any possibility of obviating this source of error, except by sliding one surface entirely on and off the other, at each move, a method which, it need not be shown, would be impracticable.

It may be mentioned, as an additional cause of error, that the grinding powder collects in greater quantity about the edges of the metal than upon the interior parts, producing the well-known effect of the bell-mouthed form. This is particularly objectionable in the case of slides from the access afforded to particles of dirt, and the immediate injury thereby occasioned.

Another circumstance materially affecting the durability of ground slides is, that a portion of the emery employed becomes fixed in the pores of the metal, and causes a rapid and irregular wear of the surfaces.

If grinding be not adapted to form a true general outline,

neither is it to produce accuracy in the minuter detail. There can be little chance of a multitude of points being brought to bear, and distributed equally, under a process from which all particular management is excluded. To obtain any such result, it is necessary to possess the means of operating independently on each point, as occasion may require, whereas grinding affects all simultaneously. It is subject neither to observation nor control. There is no opportunity of regulating the distribution of the powder, or of modifying its application, with reference to the particular condition of different parts of the surface. The variation in the quantity of the powder and the quality of the metal, will, of necessity, produce inequalities, even supposing they did not previously exist. Hence, if a ground surface be examined, the bearing points will be found lying together in irregular masses, with extensive cavities intervening. An appearance, indeed, of beautiful regularity is produced, and hence, no doubt, the universal prejudice so long established in favor of the process. But this appearance, so far from being any evidence of truth, serves only to conceal error. Under this disguise surfaces pass without examination, which, if unground, would be at once rejected.

Another evil of grinding is, that it takes from the mechanic all sense of responsibility, and all spirit of emulation, while it deludes him with the idea that the surface will be ultimately ground true. The natural consequence is, that he slurs it over, trusting to the effect of grinding, and well knowing that it will efface all evidence either of care or neglect on his part.

It thus appears that the practice of grinding has altogether impeded the progress of improvement. A true surface, instead of being in common use, is almost unknown.* Few

* This, it must be borne in mind, had reference to the state of things existing in 1840.

mechanics have any distinct knowledge of the method to be pursued for obtaining it, nor do practical men sufficiently advert, either to the immense importance, or to the comparative facility of the acquisition.

Due latitude must be allowed to the expression "true surface." Absolute truth is confessedly unattainable. Moreover, it would be possible to aim at a degree of perfection beyond the necessity of the particular case, the difficulty of attaining which would more than counterbalance its advantage. But it is certain that the progress hitherto made falls far short of this practical limit, and that considerations of economy alone would carry improvement many degrees higher. The want of it in various departments of the arts and manufactures is already sensible. The valves of steam engines, for example;—the tables of printing presses—stereotype plates—surface plates—slides of all kinds, require a degree of truth much superior to that they generally possess. In these, and a multitude of other instances, the want of truth is attended with serious evils. In the case of the slide valves of steam engines, there is occasioned a great loss of steam power, and also an immense increase of wear and tear.* In stereotype printing, inaccuracy of the plates renders packing

* Mr. Dewrance, superintendent of the locomotive department of the Liverpool and Manchester Railway, in a letter to Mr. Whitworth, dated the 23d of December, 1840, says :—"In answer to yours of the 20th inst., respecting the difference of the slide valves got up with emery, and those that are scraped or got up according to your plan, the difference is as follows :—I have this day taken out a pair of valves got up with emery that have been in constant wear five months, and I find them grooved in the usual way. The deepest grooves are one-eighth of an inch deep, and the whole surface, which is eight inches broad, is one-sixteenth hollow, or out of truth. Those that were scraped are perfectly true, and likely to work five months longer."

necessary to obtain a uniform impression. A vast amount of time and labor is thus sacrificed, and the end is, after all, but imperfectly attained.

The extensive class of machinery, denominated engine tools, affords an important application of the subject. Here every consideration combines to afford accuracy. It is implied in the very name of the planing engine. The express purpose of that machine is to produce true surfaces, and it is itself constructed of slides, according to the truth of which will be that of the work performed. When it is considered that the lathe and the planing engine are used in the making of all other machines, and are continually re-producing surfaces similar to their own, it will manifestly appear of the first importance, that they should themselves be perfect models.* There is, perhaps, no description of machinery which would not afford an illustration of the importance belonging to truth of surface, and at the same time, of the present necessity for material improvement; nor is there any subject connected with machines, the bearings of which, on public interests, whether manufacturing or scientific, are more varied or more extensive.

The improvement so much to be desired, will speedily follow upon the discontinuance of grinding. Recourse must then be had to the natural process. The surface plate and the scraping instrument will come into constant use, affording the certain and speedy means of attaining any degree of truth which may be required. A higher standard of excellence will be gradually established, the influence of which will be felt throughout all mechanical operations, while, to the mechanic himself, a new field will be opened, in which he will find

* It is plain that, in machines intended to be used in reproducing other machines, errors in surface are of the utmost consequence, for the original defects are propagated in an aggravated form.

ample scope for the exercise of skill, both manual and mental.* The subject will be best illustrated by a description of the process.

There are two cases for consideration, in reference to the preparation of surfaces—the one, where a true surface plate is already provided, as a model for the work in hand, and the other, where an original surface is to be prepared.

The former case is that which will generally occur in practice. The method to be pursued is simple, and requires care rather than skill. Coloring matter, such as red ochre and oil, is spread over the surface plate, *as equally as possible;* the work in hand, having been previously filed up to the straight edge, is then applied thereto, and moved slightly to fix the color, which, adhering to the parts in contact, afterwards shows the prominences to be removed by the scraping instrument, and the operation is frequently repeated. As the work advances, a smaller quantity of coloring matter is used, till at last, a few particles spread out by the finger suffice for the purpose, forming a thin film over the brightness of the plate. A true surface is thus rendered a test of the greatest nicety, whereby the smallest error may be detected. At this stage of the process, the two surfaces must be well rubbed together, that a full impression may be made by the color. The higher points on the rising surface become clouded over, while the other parts are left more or less in shade. The dappled appearance thus produced, shows to the eye of the mechanic, the precise condition of the new surface in every part, and enables him to proceed with confidence in bringing it to correspondence with the original. Before this can be accomplished, however, the scraping instrument must be employed, the file not having the precision or nicety requisite to

* It is satisfactory to be able to state that the results here anticipated have been long ago realized.

finish the operation. Experience will be a sufficient guide when to exchange the one for the other. It will be found, that when the parts to be operated upon have become to any considerable extent subdivided, scraping is much the more expeditious method. The instruments should be made of the best steel, and carefully sharpened to a fine edge on a Turkey-stone, the use of which must be frequently repeated. They may be conveniently made of worn-out files. It will be matter of discretion, as before remarked, how far to proceed in working up the minute detail, but it is essential that the bearing points, whether more or less numerous, should be *equally distributed*, and a uniform character preserved throughout. This rule should be carefully observed during the progress of the work, as well as at its conclusion.

In order to secure the equal advance of all the parts together, particular attention must be paid to the coloring matter, both with reference to the quantity employed, and its equal distribution. If too small a quantity be used in the first instance, it will afford no evidence of the general condition of the surface. It will merely indicate the particular points which happen to be most prominent, and to reduce these in detail would be only a waste of time, so long as they are considerably above the general level.

When the surface is finished, if it be rubbed on the plate without color, the bearing points will become bright, and the observer will be able to judge of the degree of accuracy to which it has been brought. If it be as nearly true as it can be made by the hand, bright points will be seen diffused throughout its whole extent, interspersed with others less luminous, indicating thereby the degree of force with which they respectively bear.

In getting up a surface of considerable extent, it is necessary to take into account the strain which the metal suffers from its

own weight, and the length of time required to produce the full effect on the external form. It will be found, for example, that after a piece of metal has remained for some days in one position undisturbed, it assumes a form different from that which it had while undergoing preparation. Hence, it is desirable to provide for the work while in hand, similar support to what it will have when applied to its intended use.

Another disturbing cause is the unequal contraction of the metal in cooling, when originally cast. The mass assumes the curved form, and is pervaded by elastic forces counteracting each other. These continue in permanent activity, and any portion of metal, taken from any part, tends to disturb the balance previously established.

It remains to consider the second case proposed, viz., how to prepare an original surface. A brief description of the proper method will still further illustrate the case already considered, and will also show how surface plates are to be corrected.

Take three plates of cast iron, of equal size and proportionate strength. The metal should be of a hard quality. The plates should be well ribbed on the back to prevent them from springing, and each of them should have three projecting points on which to rest, placed triangularly in the most favorable positions for bearing. The object of this provision is to insure constant support at the same points. The plate would otherwise be subject to perpetual variation of form, owing to the irregular strain, occasioned by change of bearing.* A provision of this kind is equally necessary while the plate is undergoing the operation of correction, and when it is afterwards used as a model.

* The importance of always providing a proper support for standard surfaces is still very often overlooked. The tripod system is, as I have before stated, absolutely essential.

In fixing the plates on the table of the planing machine, care should be taken to let them bear on the points before mentioned, and to chuck them with as little violence as possible to the natural form, otherwise they will spring on being released, and the labor of filing will be increased in proportion. It is proper also to relax the chucks before taking the last cut. With these precautions, if the machine itself be accurate, and the tool in proper condition, the operation of planing will greatly facilitate the subsequent process.*

The plates are next to be tried by the straight edge, by a skillful use of which a very small degree of inaccuracy may be detected.

Let one of the three plates be now selected as the model, and the others be surfaced to it with the aid of coloring matter. For distinctness they may be called Nos. 1, 2 and 3. When Nos. 2 and 3 have been brought up to No. 1, compare them together. It is evident that if No. 1 be in any degree out of truth, Nos. 2 and 3 will be alike, and the nature of their error will become sensible on comparing them together by the intervention of color. To bring them to a true plane, equal quantities must be taken in both from corresponding places. When this has been done with all the skill the mechanic may possess, and Nos. 2 and 3 are found to agree the next step is to get up No. 1 to both, applying it to them in immediate succession, so as to compare the impressions. The art here lies in getting No. 1 between the two, which is the probable direction of the true plane. It is to be presumed that No. 1 is now nearer truth than either of the others, and

* The plates, after having been planed, should be allowed to rest for two or three weeks on their three bearing points. This will afford them time to settle in the form which they will naturally assume.

it is therefore to be again taken as the model, and the operation repeated.

It will be observed that the process now described includes three parts, and consists in getting up the surfaces to one another in the following order:—

1st. Nos. 2 and 3 to No. 1.
2d. Nos. 2 and 3 to each other.
3d. No. 1 to Nos. 2 and 3.

These parts compose an entire series, by repeating which a gradual approach is made to absolute truth, till further progress is prevented by inherent imperfection.

In the earlier stages, the operation may be greatly expedited by judicious management. It has been already remarked, but it cannot be too often repeated, that the general outline of the surface should be solely regarded in the first instance, and the filling up deferred till after general truth has been secured. By this method, the first course of the series will be short, and the progress made will be both more speedy and more sure, the minuter detail being gradually entered upon, without the risk, otherwise, incurred, of losing previous labor. As, however, the surfaces approach perfection, the utmost caution and vigilance will be necessary to prevent them from degenerating. This will inevitably happen, unless the comparison be constantly made between them all.

In the use of the surface plate, care should be taken to prevent unnecessary injury, whether superficial or from straining. It should also be occasionally submitted to careful correction, and should invariably be supported on three points. In no other way can a high standard be maintained.

It will be found convenient to set apart one plate for the purpose of comparing others, allowing it to remain entirely undisturbed. It would otherwise be necessary, at every re-

vision, to repeat the process for obtaining an original surface, and a considerable loss of time would thus be occasioned.

A mistaken idea prevails that scraping is a dilatory process,* and this prejudice may tend to discourage its introduction. It will be found, however, to involve the sacrifice of less time than is now wasted on grinding. Were the fact otherwise, it would be no argument against the preference due to the former. But it is worthy of observation that, in this instance, as in many others, improvement is combined with economy. There is not only an incalculable saving effected by the improved surface, in its various applications, but there is also a positive gain of time in the preparatory process.

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* When grinding was first discontinued in the establishment of Messrs. Whitworth & Co., no mechanic could be induced to take the work on the same terms as before, owing to the supposed extra labor of scraping. But experience has entirely removed this prejudice, and the work is now done with greater dispatch.

A PAPER ON AN UNIFORM SYSTEM OF SCREW THREADS.*

THE screw threads which form the subject of this paper are those of bolts and screws, used in fitting up steam engines and other machinery. Great inconvenience is found to arise from the variety of threads adopted by different manufacturers. The general provision for repairs is rendered at once expensive and imperfect. The difficulty of ascertaining the exact pitch of a particular thread, especially when it is not a multiple or submultiple of the common inch measure, occasions extreme embarrassment. This evil would be completely obviated by uniformity of system, the thread becoming constant for a given diameter. The same principle would supersede the costly variety of screwing apparatus, required in many establishments, and remove the confusion and delay occasioned thereby. It would also prevent the waste of bolts and nuts which is now unavoidable. The impulse and direction given to machinery during late years have tended to increase these evils, and must, ultimately, lead to a change of system.† Take, for example, the refitting shop of a railway or steam packet company. Here the variety of apparatus rendered necessary by the want of uniformity will correspond with the number of different manufacturers by whom the engines are supplied, whereas, if the same system of screw threads were common to the different engines, a single set of

* Read at the Institution of Civil Engineers in 1841.

† Since 1841, when this was written, the system of screws here recommended has been universally adopted.

screwing tackle would suffice. The economy and manifold advantages resulting from uniformity in this instance, would be sufficiently obvious.

Supposing the same principle extended throughout engineering and other establishments until its application became general, the advantage would be proportionally greater, and would assume a character of public importance. Public convenience would be promoted in various ways easy to trace, though leading to results perhaps little to be expected, and the economy of screwing apparatus, however considerable, would become insignificant when compared with the contingent benefit to other interests.

Were an uniform system adopted for marine or locomotive engines there can be no doubt that it would be extended to engines and machinery of almost every description. Peculiar threads will, of course, be always required for particular purposes, but in screws for general use in fitting up machinery, the advantage of uniformity would be paramount to every other consideration.

It does not appear that any combined effort has been hitherto made to attain this object. As yet there is no recognized standard. This will not be matter of surprise, when it is considered that any standard must be, to a great extent, arbitrary. It is impossible to deduce a *precise* rule for the threads of screws from mechanical principles, or from any number of experiments. On the other hand, the nature of the case is such that mere approximation would be unimportant, absolute identity of thread for a given diameter being indispensable.

To how great an extent the choice of thread is arbitrary will appear from a cursory consideration of the principles affecting it. Without attempting to discuss these in detail, which would be foreign to the present purpose, it may be

interesting to notice the general outline and bearings of the subject.

The use of the screw bolt is to unite certain parts of machinery in close and firm contact. It is peculiarly adapted for this purpose by the compact form in which it possesses the necessary strength and mechanical power. The extreme familiarity of the object tends to prevent the observation of its peculiar fitness. Yet, among all the applications of mechanics, there is perhaps, no instance of adaptation more remarkable. The ease with which distinct parts of machinery can be united, the firmness with which they are held together, and the facility with which they may be separated, are conditions of the utmost importance, which by no other contrivance could be combined in an equal degree.

While, however, the utility of the screw in this application is abundantly obvious, it is by no means evident what may be the precise formation most advantageous under all circumstances. No exact data of any kind can be obtained for calculation, and the problem will be found to be capable only of approximate solution.

The principal conditions required in the screw bolt are power, strength, and durability—the latter having reference to the wear occasioned by frequent fixing and unfixing. But none of these conditions can be reduced to a definite quantity. We cannot, for example, determine the exact amount of power necessary to draw the parts of a machine into due contact, or the precise degree of strength which may suffice for resisting the strains to which they may be afterwards exposed. Hence, we cannot lay down any rule for choosing the diameter of the screw bolt required for a given purpose. Practical men can judge of the proper size with considerable nicety, but they have no means of ascertaining it with absolute precision.

If the diameter be given, and it be required to find the proper thread, the nature of the question is not essentially altered. The amount neither of power, nor of strength (nor any other condition) is thereby determined. A certain limit is assigned, but within that limit the proportions of strength and power, etc., may vary indefinitely, according to the actual formation of the thread.

There are three essential characters belonging to the screw thread, viz., pitch, depth and form. Each of these may be indefinitely modified independently of the others, and any change will more or less affect the several conditions of power, strength and durability. The mechanical power of the screw depends on the pitch, which for a given diameter determines the angle of the inclined plane, and on the form of thread which regulates the direction in which the force applied will act. The strength of the screw in the thread varies with each of the three characters; in the centre part, being as the area, it is little affected, except by change of depth. The durability of the thread also depends chiefly on its depth, and the proper depth is determined principally with reference to this condition. In the selection of the thread considerable latitude of choice will be found to prevail with reference to all the characters. No definite rule can be given for determining any one of them. It may be manifest that particular threads are too coarse or too fine, too deep or too shallow; but there are intermediate degrees within which the choice of thread like that of the diameter is arbitrary, and must be guided rather by discretion than by calculation.

The mutual dependence of the several conditions required in the thread may be noticed as having a tendency to perplex the choice. Thus increase of power is necessarily attended with diminution of strength. The square thread which has the advantage in respect of power is proportionally weaker

than the angular thread. A fine thread loses its strength, while it gains mechanically as compared with a coarser. Deep threads also, while they are more durable than shallow, materially detract from the strength of the bolt.

The selection of the thread is also affected by the mutual relation subsisting between the three constituent characters of pitch, depth, and form. Each of these, as before observed, may be separately modified; but practically no one character can be determined irrespective of the others. The pitch of the square thread is generally twice that of the angular for the same diameter, to retain similar proportions of power and strength. Coarse threads should be deep as compared with fine, to provide against the wear from friction. A coarse angular thread will also require additional depth to preserve the due proportion of power, and to prevent the longitudinal strain from being thrown too much sideways on the nut. Hence, each character acts as a limit to the variation of the others, and in some instances (that is, in the case of certain diameters), it will be found that the leading consideration in fixing our character is the resulting effect on another. Thus, in some of the smaller sizes, the pitch is determined principally by reference to the depth—a coarser thread being objectionable, because the extra depth would too much weaken the centre part of the bolt—while the necessary shallowness of a finer thread would render it too liable to wear with friction.

The proportional strength of the thread and centre part of the screw is regulated mainly by the depth of the nut, which is generally of the same measure as the diameter of the bolt. Assuming that dimension as fixed, the proportion of strength between the two parts will vary with the different characters of thread, and more particularly with the depth. The centre part not being liable to wear while the thread is subject to

friction and accidental injury, the original proportion of strength ought to be considerably in favor of the thread.

Such being the variety and vagueness of the principles avowed in the subject, a corresponding latitude might naturally be expected in their practical application, and accordingly we find, instead of that uniformity which is so desirable, a diversity so great as almost to discourage any hope of its removal. The only mode in which this could be attempted with any probability of success would be by a sort of compromise, all parties consenting to adopt a medium for the sake of common advantage. The average pitch and depth of the various threads used by the leading engineers would thus become the common standard, which would not only have the advantage of conciliating general concurrence, but would, in all probability, be nearer the true standard for practical purposes than any other.

Messrs. Whitworth & Company were led, some years ago, to alter the threads of their screws on this principle, in consequence of various objections urged against those they had previously adopted, and the result of the experiment has been abundantly satisfactory. An extensive collection was made of screw bolts from the principal workshops throughout England, and the average thread was carefully observed for different diameters. The ¼, ½, 1, and 1½ inches were particularly selected and taken as the fixed points of a scale by which the intermediate sizes were regulated. The only deviation made from the average was such as might be necessary to avoid the great inconvenience of small fractional parts in the number of threads to the inch. The scale was afterwards extended to 6 inches.

The pitches thus obtained for angular threads are shown in the following table :—

Diameter in Inches	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
Threads to the Inch	20	18	16	14	12	11	10	9	8	7	7
Diameter in Inches	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	3 1/4
Threads to the Inch	6	6	5	5	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/4
Diameter in Inches	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6
Threads to the Inch	3 1/4	3	3	2 7/8	2 7/8	2 1/4	2 3/4	2 5/8	2 5/8	2 1/2	2 1/2

It will be observed that above 1 inch diameter the same pitch is used for two sizes. This could not have been avoided without introducing small fractional parts. The economy of screwing apparatus was also promoted by repetition of the thread.

It is important to remark that the proportion between the pitch and the diameter varies throughout the entire scale. Thus the pitch of the ¼ inch is one-fifth of the diameter—that of the ½ inch, one-sixth—of the 1 inch, one-eighth—of the 4 inch, one twelfth—of the 6 inch, one fifteenth. It is obvious that more power is required as the diameter increases. But this consideration alone will not account for the actual deviation, which is much less than it would be if the scale were calculated with reference to the power required. The amount of power necessary must be determined in relation to the muscular force of the human arm, aided by the leverage of the screw key. Now, in the case of smaller screws, there is a considerable excess of force. Again, in the larger, there will be found a deficiency of power, for with all the leverage which can generally be applied, it requires the force of several men to fix a bolt of six inches diameter. Hence, it is evident that at the two extremes of the scale the amount of power required is not the leading consideration in fixing the pitch of the thread. In the smaller sizes the necessary depth of a

coarser thread—as before observed—would too much weaken the centre part of the screw. It may also be mentioned that coarse threads would render small screws apt to work loose for want of sufficient hold to prevent the effect of jarring. On the other hand, finer threads on large bolts besides being weaker and less durable, would render it difficult to unfix them when occasion required.

It will be remembered that the threads, of which the preceding table shows the average, are used in cast iron as well as wrought; and this circumstance has had its effect in rendering them coarser than they would have been, if restricted to wrought iron.

The variation in depth among the different specimens was found to be greater proportionally than in pitch. The angle made by the sides of the thread will afford a convenient expression for the depth. The mean of the variations of this angle in 1 inch screws was found to be about 55°, and this was also pretty nearly the mean of the angle in screws of different diameters. As it is for various reasons desirable that the angle should be constant, more especially with reference to general uniformity of system, the angle of 55° has been adopted throughout the entire scale. A constant proportion is thus established between the depth and the pitch of the thread. In calculating the former, a deduction is to be made for the quantity rounded off, amounting to one-third of the whole depth—that is, one-sixth from the top, and one-sixth from the bottom of the thread. Making this deduction it will be found that the angle of 55° gives for the actual depth rather more than three-fifths, and less than two-thirds of the pitch. The precaution of rounding off is adopted to prevent the injury which the thread of the screw, and that of the taps and dies, might sustain from accident.

The system of threads selected in the manner above de-

scribed has already obtained greater extension than any other. It has been adopted exclusively on many of the railways, and in some of the most extensive engineering establishments in England and Scotland. During the present year it has been introduced into the Royal Dockyard at Woolwich, and it is now being applied to the engines constructing for the Royal Mail Steam Packet Company. There is, therefore, reason to hope this system may be instrumental in promoting the proposed object of uniformity, of which it already exemplifies the practicability and advantage.

But the difficulty of obtaining a concurrence of opinion in favor of a particular system is not the only one to be encountered. The inconvenience to existing establishments which any change would involve is calculated to retard the prevalence of an approved system, nor could general co-operation be reasonably expected unless there were a certain prospect of success. This, however, is an obvious reason why the attention of engineers should, without loss of time, be directed to the subject.

It will probably occur to practical men that there are other obstacles to be surmounted before the principle of uniformity can be carried into full operation. The great want of accuracy in screwing and tapping by the ordinary process may be particularly mentioned. To whatever extent this may prove an obstruction, it may be also regarded as an additional motive for urging the subject on general attention. The necessity for greater correctness will thus be placed in a new and stronger light, and the effect no doubt will be a material improvement in this essential respect. It is mainly for want of accuracy that screw bolts so frequently fail. Unless the threads of the screw and nut exactly correspond in every part, and coalesce throughout their whole length and depth, their mutual action is completely deranged, power and

strength are both sacrificed, and friction is proportionally increased. The immense consumption of bolts and nuts in fitting up and working machinery may give some idea of the extent to which greater accuracy might be productive of economy.

To maintain uniformity, provision must be made for multiplying standards of the diameters and threads. This may be easily done, and will prevent the screwing tackle from degenerating by use and propagation.

This part of the case is connected with a subject of great extent, which, under every aspect, lays claim to the attention of practical engineers. We allude to the general use of standard gauges, graduated to a fixed scale, as constant measures of size. It is quite practicable by such means to work to a common measure with a degree of accuracy sufficient for all ordinary purposes. Corresponding parts, instead of being got up one to another, might be prepared separately. The indefinite multiplication of sizes would thus be prevented, and the economy of the workshop simplified to an extent beyond calculation.

ADDRESS TO THE INSTITUTION OF MECHANICAL ENGINEERS.*

GENTLEMEN—This being the first time I have taken the chair since you did me the honor to elect me your President for the present year, I propose to address you shortly on a few topics more or less connected with our profession of mechanical engineering. But first, let me express my gratification, and I am sure that of my fellow-countrymen, in thus meeting our northern friends in this important city.

Glasgow is particularly interested in the mechanical arts, for the minerals for making iron are found in great abundance in this locality; indeed, it is to this neighborhood, more than to any other, that the world is indebted for the cheapest and most abundant supply of iron. Here, too, that metal is converted into a great variety of machinery. There are large manufactories of the steam engine—fixed, marine, and locomotive. Cotton manufacturing, and various other kinds of machinery are also made here in considerable quantities. With such links of connection amongst us, I trust that this, our first meeting in this city, may be the forerunner of many others, and that we shall add many members to our Institution.

Great attention is now being paid to improvements in the manufacture of malleable iron and steel. I need not tell you of what vast importance it must be to those who are more immediately connected with those branches of mechanics re-

* Delivered at Glasgow, 1856.

quiring nicety of workmanship, to have iron and steel of a better quality. I may mention that in making rifle-barrels for the experiments which I have undertaken for the Government, one of the greatest difficulties I encounter, in attaining the degree of accuracy that I require, arises from the defects in the metal. What we want is iron of great strength, free from seams, flaws, and hard places. Inferior iron (with the use of other defective and improper materials) is perhaps the main cause of one of the greatest errors committed in the construction of whatever in mechanism has to be kept in motion. I mean the increase of size of the parts of a machine or carriage, in order to get strength, thereby adding weight until they are considered to be strong enough. In our vehicles of draught and carriages this is strikingly the case. Now this ought not to be. Lightness is the thing to aim at, and safety should be sought in the elasticity, form and good quality of the material. Should a carriage be found to twist and get out of form, that would be a proof of its being too light. But to prevent a carriage breaking down by increasing the size of its parts, and thereby adding weight, instead of improving quality, is mechanically wrong. Indeed, it is quite distressing to see the enormous weight of our carriages, particularly those drawn by animal power. It should be an axiom in mechanics that whatever has motion should be as light as circumstances will admit; this applies equally, whatever the source of power may be, whether the motion is produced by human, horse, or steam power.

I would next call your special attention to the vast importance of attending to the two great elements in constructive mechanics—namely, *a true plane* and *the power of measurement*. The latter cannot be attained without the former, which is therefore of primary importance; and its accomplishment is so easy and so simple as to leave without

excuse any establishment neglecting to secure it. It is necessary to make three planes in order to obtain a perfect one, and cast iron is the best material generally to use. Whatever the size of the plane required, the tripod form is absolutely essential for its support; and the strengthening ribs must be placed with reference to the supports. I cannot impress too strongly on the members of the Institution, and upon all in any way connected with mechanism, the vast importance of possessing a true plane, as a standard for reference. All excellence in workmanship depends upon it. I may mention that it was at the meeting of the British Association held in Glasgow in 1840 that I read a paper on the mode of producing a true plane, to which I would refer those desiring information on the subject.*

Next in importance to a true plane is the power of measurement. I have brought with me, for your inspection at the close of the meeting, a small machine, by which a difference in length of the one-millionth part of an inch is at once detected. The principle is that of employing the sense of touch, instead of sight. If any object be placed between two parallel true planes, adjusted so that the hand can just feel them in contact, you will find, on moving the planes only the 50-thousandth of an inch nearer together, that the object is distinctly tighter, requiring greater force to move it between them. In the machine before you, the object to be measured is the standard inch, in the form of a small square bar, both ends being true planes; and in this case, in order to measure with the utmost accuracy, a thin flat piece or bar is introduced, having its two sides made also perfect planes. This is placed between the inch bar to be measured and one of the end surfaces of the machine. This thin bar, which I

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* See ante pages 73—84.

name the gravity piece, is brought into contact with the two planes, so as just to allow it, on being raised, to fall by its gravity; and you will find that, by bringing the planes into closer contact by even the one-millionth of an inch, the gravity piece will be suspended, friction overcoming its gravity. This machine and a larger one, are used for making standards of length. When the standard yard, which is a square bar of steel, is placed in the larger machine, and the gravity piece adjusted so as just to fall by its weight, the heat imparted from the slightest touch of the finger instantly prevents its fall, thus showing the lengthening of the bar by so small an amount of heat as that I have indicated. We have therefore in this mode of measurement all the accuracy we can desire; and we find in practice in the workshop that it is easier to work to the ten-thousandth of an inch from standards of end measure, than to the one-hundredth of an inch from the lines on a two-foot rule. In all cases of fitting, end measures of length should be used, instead of lines.

The question of correct measurement is in immediate connection with another, which will repay all the attention that can be given to it, and I think there is no subject that can be more profitably discussed amongst us—I mean that of *proper gradations of size* in all the various branches of the mechanical arts. I think no estimate can be formed of our national loss from the over multiplication of sizes. Take for instance the various sizes of steam-engines—stationary, marine, and locomotive. In the case of marine engines, the number of sizes up to 100 horse-power will probably not be short of thirty, where ten perhaps would be ample. If so, look at the sums expended in patterns, designs, and in the number of tools for their manufacture. Nor is this all; for if there were only ten sizes instead of thirty, there would be three times the number made of each pattern; and, as you know, the very soul of

manufacture is repetition. By attention to this, the ship-owner would be benefited by getting a better engine at a less price. In the case of locomotives and carriages, I would urge the subject on the attention of our members, the engineers of the great lines of railway—the London and North-Western, the Midland, the Great Northern, for instance. I hope they will permit me to suggest that they should consider and determine not only the fewest possible number of sizes of engines and carriages that will suffice, but also how every single piece may have strictly defined dimensions. This question is also well worthy attention of our architects and builders. Suppose, for instance, that the principal windows and doors of our houses were made only of three or four different sizes. Then we should have a manufactory start up for making doors, without reference to any particular house or builder. They would be kept in stock, and made with the best machinery and contrivances for that particular branch; consequently, we should have better doors and windows at the least possible cost. Our friends across the Atlantic manage matters in connection with their buildings much better than at present we do.

I hope the members of this Institution will join me in doing what we can with reference to those two important subjects—correct measurement, and its corollary, proper gradations of size. The want of more correct measurement seems to prevade everything. Take, for instance, the case of the common brick, which ought to be three inches thick. Who is there that has made an addition to a building who has not felt inconvenience from the irregularity of size—the new brick being, perhaps, too thick, and so not allowing sufficient mortar to be used; or too thin, and requiring too much mortar.

Perhaps one of the most effectual means that could be

adopted, in the first instance, to remedy this unsatisfactory state of things, would be for the Government to supply corporate bodies with proper standards of length—such as the inch, the foot, and the yard. The corporate bodies themselves might then have their own standards of size, founded on these, and made to suit the particular wants of the different trades in the locality. The only standard of length at present supplied by the Government and kept by the corporate bodies is the standard yard; but there is so little attention paid to accuracy, that to engineer and machinist it is not of the slightest use, and is only employed to adjust yard sticks for measuring woven goods.

There is also another subject which bears upon this question, and which has lately been before the Legislature—that of decimalizing weights and measures. There can be no doubt of the beneficial results that would follow the passing of such a measure. There may be a difference of opinion as to what the unit or integer of lineal measure should be; but I think that it should be the inch, for, from the accuracy with which we can now measure that length, there would be no difficulty in determining and fixing the length of its multiples. The most important divisions of length in mechanism are those of parts of an inch, and if the length of the inch were altered it would cause much confusion. Small accurate standards of length, of the decimal parts of an inch, would be of much service to some traders. There is now no standard of appeal; and the different wire and other gauges, differ so considerably, that the manufacturer, in the case of small wire and sheets of metal, has to send a sample of what he wants, there being no means of correctly expressing its size.

Although I have said so much to you with reference to the desirableness of further improvement and greater perfection

in the mechanical arts, I congratulate you on the success which in our time they have attained, and the high consideration in which they are held. Inventors are not now persecuted, as formerly, by those who fancy that their inventions and discoveries are prejudicial to the general interests, and calculated to deprive labor of its fair reward. Some of us are old enough to remember the hostility manifested to the working of the power-loom, the self-acting mule, the machinery for shearing woollen cloth, the thrashing machine, and many others. Now, the introduction of the reaping and mowing machine, and other improved agricultural machinery, is not opposed. Indeed, it must be obvious to reflecting minds that the increased luxuries and comforts which all, more or less, enjoy, are derived from the numerous recent mechanical appliances and the production of our manufactories. That of our cotton has increased during the last few years in a wonderful degree. In 1824, a gentleman with whom I am acquainted sold on one occasion one hundred thousand pieces of 74 reed printing cloth at 30*s.* 6*d.* per piece of 29 yards long; the same description of cloth he sold last week at 3*s.* 9*d.* One of the most striking instances I know of the vast superiority of machinery over simple instruments used by the hand is in the manufacture of lace, where one man with a machine does the work of 8,000 lacemakers on the cushion. In spinning fine numbers of yarn, a workman on a self-acting mule will do the work of 3,000 hand-spinners with the distaff and spindle; and there are other striking facts of a similar kind mentioned in my Report on the New York Industrial Exhibition.

Comparatively few persons, perhaps, are aware of the increase of production during our lifetime. Thirty years ago, the cost of labor for making a surface of cast iron true, by chipping and filing by the hand, was 12*s.* per square foot;

the same work is now done by the planing machine at a cost for labor of less than 1*d.* per square foot, and this, as you know, is one of the most important operations in mechanics. It is therefore well adapted to illustrate what our progress has been. At the same time that this increased production is taking place, the fixed capital of the country is, as a necessary consequence, augmented; for, in the case I have mentioned of chipping and filing by the hand, when the cost of labor was 12*s.* per foot, the capital required for tools for one workman was only a few shillings; but now the labor being lowered to 1*d.* per foot, a capital in planing machines for the workmen is required, which often amounts to £500, and in some cases more. This large outlay of capital, invested in machinery to increase production, makes it very difficult to curtail the hours of working machinery, as much as could be desired. In some cases two sets of work-people have been employed in relays, each working eight hours a day; and this system perhaps may in time be extended, although it is attended with certain inconveniences. If, however, the relay system could be so improved and organized as to allow more time for the better education of young operatives, none would more cordially rejoice than myself. I believe that the science of mechanics, though a mere material power in itself, may, if rightly used, become a moral lever, by which, like Archimedes of old, we may seek to raise the world.

There is at the present time a very gratifying circumstance in connection with the extension of machinery; namely, the large renumeration which operatives who work machines actually receive compared with those who perform hand labor without the help of machinery. I would here mention, with reference to the amount of wages paid to the operative, that it does not depend solely on the master manufacturers of

this country, but is governed in some measure by what is paid by the manufacturers of other countries who are in competition with our own. When I was in America in 1853, I found that the American operatives received somewhat more wages than are paid in this country; but they worked much longer hours, although the climate, during some parts of the year, is so unfavorable. These longer hours enable the American manufacturer to turn over his capital more frequently.

This question of increased production, with which we, as mechanical engineers, are so identified, is so entirely dependent upon the power of the people to consume, that I hope I shall be excused in adverting to it. Our yearly exports now amount to about a hundred millions sterling, having doubled in a short time, while our home productions have been greatly increased from the same cause, namely, the increased ability of our people to consume. As a general principle it would seem to be far better to levy a small impost on the entire wealth of an individual rather than to fasten a tax on particular objects, which if produced would constitute wealth, but which are not made because of the threatened impost. The remaining duty on carriages seems to me to be one of this description. Were there no tax, almost every one who keeps one carriage would keep more, while large numbers would have one who now have none. By their use locomotion would be increased threefold, and hence much valuable time would be saved. Besides, a large number of the best description of artisans would be called into existence for their manufacture—a class, too, who are well able to turn their hand, in cases of necessity, to other employment. If, therefore, it is desirable for a nation to possess wealth in carriages, it is a mistake for legislation to prevent it.

Formerly, when the wealth of a nation was produced, as

it were, by hand labor, a different state of things existed to that of the present day. As I have shown, our means of production are now increased in some cases more than a hundred and in others more than a thousand fold; and this will go on, just in proportion as the masses of our people are able to consume larger quantities of everything that they require. When the farm laborer pays less for his sugar and tea, more meat will be consumed (which again goes to improve the land); also more wool for our manufactures.

In this wonderful power of producing wealth which now exists, none can be more interested and benefited than the proprietors of the land. A striking proof of this is given by its increased value in the manufacturing counties, and for miles adjoining our manufacturing towns. The competition, too, of our manufacturers and merchants to become possessors of land is shown by the small rate of interest with which they are satisfied, for the outlay of their capital on the soil. The proprietors of land may rest assured that, in the future development of mechanical improvements, none will be more benefited than themselves. I do not hesitate to say that all harvest operations on land, properly laid down, will very shortly be performed in one-fourth the time required with the hand labor now expended, by the farther application of machines worked by horse-power. This is my conviction, based upon the experience I have had in the successful working of the machine I constructed for sweeping the streets, and at the same time filling the cart, by horse-power. By the combined aid of mechanical improvements and the science of chemistry, together with the greater skill of our modern agriculturists, the culture of the land throughout Great Britain must more and more approximate to that of a garden.

We have seen the effect of the repeal of the duties on

glass and bricks, in the improved appearance and reduced cost of residences, and a still further benefit may be expected to result from the removal of the remaining duty on timber. While, therefore, we congratulate ourselves on the great results which the mechanical arts have achieved; we have every reason to be thankful that our legislators have removed so many impediments to our progress. The glorious fruits of the legislative labors of that great and good man, Sir R. Peel, may give us hope that the time is not far distant when all remaining obstacles of this kind will be swept away. When that period has arrived, and when the industry of this country has been systematized upon sound principles of economical science, and in each department carried nearer to those standards which, in the case of mechanics, I have endeavored to indicate, we shall have less reason than at present to doubt the stability of our manufacturing pre-eminence.

STANDARD DECIMAL MEASURES OF LENGTH.*

In the address which I had the honor of delivering before the Members of this Institution at the Glasgow meeting last year, I briefly alluded to the beneficial results which would follow the application of the decimal system to our weights and measures, referring more particularly to the latter. In compliance with the wish expressed by several members of the Council, I propose in the present paper to bring this important subject more prominently under the notice of the members, confining myself, however, to its practical bearing on mechanical operations, without discussing different systems of notation, which I leave to other and abler hands.

I have long been convinced that great and rapid progress would be made in many branches of the mechanical arts if the decimal system of measures could be generally introduced. To state the case broadly, instead of our engineers and machinists thinking in eighths, sixteenths and thirty-seconds of an inch, it is desirable that they should think and speaks in tenths, hundredths, and thousandths. I can assure those who have been accustomed to the fractional system that the change to the more perfect decimal one is easy of attainment, and, when once made, it will from its usefulness and convenience amply repay any trouble which may have attended its acquirement. In the manufacture of my standard gauges of size, the workmen measure to the 1-20,000 of an inch, and these measures are as familiar and appreciable as

* **Read at the meeting of the Institution of Mechanical Engineers, at Manchester in 1857.**

those of any larger dimensions. It will therefore be at once conceded that the only scale of measurement which can be used for such small sizes and proportionally small differences must be a decimal one, as any other would be productive of insurmountable difficulty, if not of utter confusion.

When the sizes of the fitting parts of machines are determined by sight from the lines on a scale or a two-foot rule, such nicety of measurement is out of the question; and as long as they are made on that system, the progress of improvement will be retarded. My experience has satisfied me that no system of measurement depending on the power of sight is suitable for obtaining the size of the working parts of machines. Where exact size or good fitting is required, the sense of touch is far more to be depended upon. I make standards of size by a system of measurement depending for its accuracy upon the sense of touch; and use an instrument provided with a mechanical multiplier, by which a space is presented to the eye many thousand times greater in extent than is the case where the distance is directly measured by sight only.

With truth of surface, that never-failing element of success, as the basis of operation, we are enabled to measure with exactitude; and there is no difficulty in making parts of machines to fit one another with any degree of nicety; but, when we wish to express correctly by the common fractional system very minute measurements, our ideas are cramped and hampered by an inconvenient and often confused system of notation. What exact notion can any man have of such a size as "a bare sixteenth" or "a full thirty-second;" and what inconvenient results may ensue from the different notions of different workmen as to the value of these terms. A scale of notation that may have suited the old system of manufacture has been left behind, I am happy to say, as the present

age has improved on the past; and our improvement has created a want which necessity urges us to supply without delay. In the production of duplicate parts of machinery, correct measurement is indispensable to ensure good work; and if, as is the case, we are able to measure with all the accuracy and nicety that can be required, we surely ought at once to adopt a system of notation which will properly represent our measurements.

As an illustration of the importance of very small differences of size, I have brought an internal gauge having a cylindrical aperture ·5770 inch diameter, and two external gauges or solid cylinders, one being ·5769 inch, and the other .5770 inch diameter. The latter is 1-10,000th of an inch larger than the former, and fits tightly in the internal gauge when both are clean and dry; while the smaller ·5769 inch gauge is so loose in it as to appear not to fit at all. These gauges are finished with great care, and are made true after being casehardened. They are so hard that nothing but the diamond will cut them, except the grinding process to which they have been subjected. The effect of applying a drop of fine oil to the surfaces of these gauges is very remarkable. It will be observed that the fit of the larger cylinder becomes more easy, while that of the smaller becomes more tight. These results show the necessity of proper lubrication. In the case of the external gauge ·5770 inch diameter, the external and internal gauges are so near in size that the one does not go through the other when dry, and if pressed in, there would be danger of the surface particles of the one becoming imbedded in or among those of the other, which I have seen happen, and then no amount of force will separate them; but with a small quantity of oil on their surfaces, they move easily and smoothly. In the case of the external gauge .5769 inch diameter, which is 1-10,000th of an inch smaller

in diameter than the internal gauge, a space of half that quantity is left between the surfaces; this becomes filled with the oil, and hence the tighter fitting which is experienced.

It is therefore obvious both to the eye and the touch, that the difference between these two cylinders of 1-10,000th of an inch is an appreciable and important quantity; and what is now required is a method which shall express systematically and without confusion a scale applicable to such minute differences and measurements; it should be based on a uniform principle which will accustom the workman to speak of his measures as aggregates of very small differences; and when a good workman becomes familiar with such sizes as 1-1000th and 1-10,000th of an inch, he will not rest satisfied until he can work with corresponding accuracy. He will also be able to judge of their effect under different circumstances, and know how much to allow in the fitting parts of a machine, according to their relative importance and the treatment they are likely to receive at the hands of the attendant. For instance, the cylinder of the moving head-stock of a lathe requires as good a fit as possible; but in practice it is found that the cylinder must be .0005 inch or 1-2000th of an inch too small, because it frequently happens that machinery is not kept in a proper state of cleanliness, or from motives of false economy is lubricated with bad oil. These are two evils which are productive of great mischief. The abrasion caused by accumulated dust and grit produces increased wear and tear, and soon injures the surfaces in contact; while bad oil becomes sticky and rancid, and spoils the working of a good fit.

And here let me state what I think is the proper definition of a good fit. A tight fit is not necessarily a good one; but when the surfaces are true, and a proper allowance is made

in the size of the parts working together, then a good fit is obtained. What constitutes a proper allowance or difference in size depends on the nature of the case, and the treatment which the machinery will meet with. In machinery supplied to establishments using rape oil there must be greater allowance and looseness in the fits than would be requisite if better oil, as sperm oil, were used. I need scarcely say how much more advisable it is to have the more accurate fit and use the best oil, than to have a loose fit and use the inferior oil, which causing more friction consumes greater power.

Again, a good workman acquires by experience an intuitive knowledge of the allowances in size which are requisite in various cases; and if a suitable decimal system of notation be adopted, there will be no difficulty, with the power of measurement we now posses, in registering minute differences; and so the knowledge gained by the experienced workman may be imparted to others in precise terms, which to the young beginner will be of invaluable service. Much important information may by these means be stored up, and at any time reference can be made to the experience of the past, which will then run no risk of being lost through disuse, inattention, or other causes.

The deterioration of templates or patterns of size, from their becoming worn or altered in process of time, is productive of great inconvenience, as many of us perhaps have experienced. For when an original standard was thus altered, it was irretrievably lost, because there were no means of ascertaining and recording the exact measure. It is of great importance to the manufacturer who makes parts of machines in large quantities to have the means of referring to an accurate fixed measure; it will enable him to reproduce at any time a facsimile of what he has once made, and so preserve a system of sizes of the fitting parts unaltered. The greatest care

should be taken to make standards of size correctly at first, and to preserve them unaltered. Errors in the standards are not only propagated in the copies, but are superadded to the errors in the workmanship, which will occur in the course of manufacture; and this is especially likely to occur in cases where one manufacturer supplies parts of machines for the use of another.

My argument is shortly this:—If we had a better system of notation for our measures, in which small differences in size were expressed in terms conveying their value to the mind, the importance of minute and accurate measurements would become more familiar, more appreciated, and more generally applied. Many operations would by that means be more easily and effectually performed, and in some cases greater safety will be the result. Take for instance the present method of proving guns, which are proved by firing them with a considerable charge of powder and shot. If the barrel stands the proof without manifest injury, it is passed as a good one, while it may in the very process of proof have received such permanent injury as to render it highly dangerous for use. How much better it would be after proving the barrel to measure it, and ascertain accurately if any, and what, permanent alteration had taken place, and retain or reject it accordingly. This would be substituting an exact and satisfactory system for an uncertain and dubious trial; but, inasmuch as the degrees of alteration will be various, and the differences in their measurement very minute, a better system of notation with the improved mode of measuring is required, to enable this and other similarly useful applications to be made.

After careful thought and a comparison of different scales, I have come to the conclusion that the scale for standards of size given in the accompanying Table is the one I would

recommend to be adopted. I have endeavored to arrange one which would be easily intelligible to the ordinary workman, and that would in every possible case coincide with the old system, so as not to cause more expense in altering the present sizes than may be absolutely necessary. I am perfectly aware that other scales may be devised more complete and more advantageous in many respects, if we were now prepared not merely to revolutionize, but to abandon what has been manufactured and is now in use. But would not that be going too far? As long as the machines already made are in existence, the sizes of their parts cannot be abandoned; and these considerations have induced me to propose a scale which shall combine the greatest possible advantages with the least possible change.

It would be desirable that those establishments which may decide upon adopting the decimal scale should introduce rules having the inch divided into tenths and their subdivisions, which would soon become as familiar to the workman as the eighth scale he now uses.

The scale proposed for the wire-gauge commences with the smallest size and increases by thousandths of an inch up to half an inch. Contrary to the custom usually adopted in marking the wire-gauge, I have called the smallest size No. 1, being 1-1000th of an inch, No. 2 being 2-1000ths of an inch, and so on; increasing up to No. 20 by 1-1000th of an inch between each number; from No. 20 to 40 by 2-1000ths; from No. 40 to No. 100 by 5-1000ths of an inch. I propose therefore to suppress the use of the numbers of designation which have been hitherto employed for the various wire-gauges, and simply call the sizes by their expressive numbers in thousandths of an inch, as shown in the accompanying table of wire-gauges; a change which will, I think, render the new scale easily intelligible and convenient for use.

STANDARDS OF SIZE.

PROPOSED STANDARDS OF SIZE FOR TAPS AND DIES.

No. of Screw Threads per inch.	Old Sizes.	NEW STANDARDS OF SIZE. Decimals of an inch.	No. of Screw Threads per Inch.	Old Sizes.	NEW STANDARDS OF SIZE. Decimals of an Inch.
48		·100	7	1⅛	1·125
40	⅛	·125	7	1¼	1·250
32		·150	6	1⅜	1·375
24		·175	6	1½	1·500
24		·200	5	1⅝	1·625
24		·225	5	1¾	1·750
20	¼	·250	4½	1⅞	1·875
20		·275	4½	2	2·000
18		·300			
18		·325	4½	2⅛	2·125
18		·350	4	2¼	2·250
16	⅜	·375	4	2⅜	2·375
16		·400	4	2½	2·500
14		·425	4	2⅝	2·625
14		·450	3½	2¾	2·750
14		·475	3½	2⅞	2·875
12	½	·500	3½	3	3.000
12		·525	3¼	3¼	3·250
12		·550	3¼	3½	3·500
12		·575	3	3¾	3·750
12		·600	3	4	4·000
11	⅝	·625	2⅞	4¼	4·250
11		·650	2⅞	4½	4·500
11		·675	2¾	4¾	4·750
11		·700	2¾	5	5·000
10	¾	·750	2⅝	5¼	5·250
10		·800	2⅝	5½	5·500
9	⅞	·875	2½	5¾	5·750
9		·900	2½	6	6·000
8	1	1·000			

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·001	1					
·002	2					
·003	3					
·004	4	36		1	19	
·005	5	35		2	18	
·006	6	..		..	..	
·007	7	34		..	17	
·008	8	33		3	16	
·009	9	32		..	15	
·010	10	31		4	14	
·011	11	..	..	..	..	
·012	12	30	..	5	13	
·013	13	29	80	6	12	
·014	14	28	79	..	11	
·015	15	..	78	7	..	
·016	16	27	77	8	10	
·017	17	..	..	..	..	
·018	18	26	76	..	9	6
·019	19	..	75	9	..	7
·020	20	25	..	..	8	8
·022	22	24	74	..	7	10
·024	24	23	72	10	6	12
·026	26	..	71	..	..	13
·028	28	22	70	11	5	14
·030	30	..	68	..	..	15
·032	32	21	66	..	4	15
·034	34	..	64	12	..	17

·036	36	20	62	13	3	18
·038	38	..	61	..	..	19
·040	40	19*	59	14	2*	20*
·045	45	..	56	15*	1	
·050	50	18	55	16		
·055	55	..	54	17*		
·060	60	17*	52	18		
·065	65	16	51	19		
·070	70	15*	49	21*		
·075	75	..	47	22		
·080	80	..	45	24*		
·085	85	14*	43	..		
·090	90	..	42	..		
·095	95	13	41	25		
·100	100	..	38	26**		
·110	110	12	34	27**		
·120	120	11	31*	28		
·135	135	10	29	31*		
·150	150	9*	23	34*		
·165	165	8	19	36*		
·180	180	7	13			
·200	200	6**	5			
·220	220	5	2			
·240	240	4*	C			
·260	260	3	G			
·280	280	2**	K			
·300	300	1	N*			
·325	325	..	P*			
·350	350	..	S*			
·375	375	00**	V*			
·400	400	..	X**			
·425	425	000				
·450	450	0000**				
·475	475					
·500	500					

NOTE.—These Nos. correspond exactly or within ·001 inch with the new proposed Nos., except those marked *, which are within ·002 inch, and those marked **, which are beyond ·002 inch.

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